DX-ing and
Short Wave Radio

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DX-ing AND SHORT WAVE RADIO

Short Wave / H.F. Radios:

Target HF3 short wave HF receiver

TARGET HF3 AM/SSB COMMUNICATIONS RECEIVER "There is no greatness where there is no simplicity." (Leo Tolstoy)

I am often asked what would be a good H.F. receiver. There are quite a number to choose from and having previously owned a Lowe HF-150 which has now sadly been discontinued, I think that the Target HF3 could now make a very interesting proposition. I particularly admire the simplicity of its appearance. As Leonardo da Vinci noted; "Simplicity is the ultimate sophistication."

Spectrum Communications are the dealers for the Target HF3 receiver (2012) and Tony Nailer comments: "This is a masterpiece of RF engineering covering the entire spectrum between 30KHz to 30MHz. The receiver is supplied with a comprehensive instruction manual, which includes a list of useful marine frequencies. Controls on the front of the receiver change reception mode, from a narrow filter for SSB reception to a wide filter, which enables high quality AM signals to be received from broadcast stations around the world. They also control ten memory channels to store your favourite frequencies. The receiver uses a 45MHz first IF and has a high side fully synthesized local oscillator providing exceptional stability. A large, clear liquid crystal display shows the precise receive frequency. It has a fixed level audio output to connect to a computer sound card. Supplied with a basic wire antenna and 12 volt power cable." To conclude I will recall Albert Einstein who noted: "Everything should be made as simple as possible, but not simpler."

Tune in to short wave radio broadcasts - check stations and frequencies at [Link - www.shortwaveschedule.com >>](#)

Some other previously available short wave (HF) radios:

Sony ICF SW 7600 GR

Roberts R9914

Above - The excellent Sony and Roberts radios are neat portables suitable for Short Wave listening and a spot of MW, LW and VHF DX-ing too. Both models offer many facilities and very good reception.

The Palstar R30 >> Communications Receiver is for the serious Short Wave Listener who wishes to catch some exotic DX, it's easy to use and offers high performance and excellent value for money! Click HERE >> to find out more.

Some other 'classics':

Lowe HF-150 >>

Lowe HF-225 >>

TARGET (AKD) HF3 >>

Above are the Lowe >> HF-150 and HF-255 communications receivers, high quality classics that will be sadly missed now that Lowe Electronics have recently discontinued production of radios in Britain. The excellent little HF3 was, until 2003, produced by AKD Products of Stevenage. AKD Products produced the HF3 receiver together with a number of other communications products such as RF filters, but have now ceased trading. The rights to the AKD range have been aquired by Garex Electronics www.garex.co.uk >> who will be marketing some of the former AKD products and, perhaps, the HF3 too.

So now you have your radio - What is DX-ing and why?

DX-ing is the long distance reception of a distant radio station or transmitter that is not usually intended for reception at your own locality.

Despite the advent of DAB digital radio and radio delivered by satellite there is is still much fun to be had with long distance reception ("DX-ing") of long-wave, medium-wave and short-wave radio stations and even v.h.f/FM too.

DAB certainly gives a good choice of some of the mainstream stations but, in the main, listeners can only receive what the authorities intend us to hear. A DAB multiplex uses a Single Frequency Network to carry the signals to

the listener. The single frequencies are used and re-used all over the country to obtain a wide coverage, unlike traditional AM and FM broadcasting which must use a different frequency for each area or region to avoid interference.

The Single Frequency Network of DAB provides robust reception, but does not generally allow DX-ing since the frequency of the local multiplex may be the same as the multiplex that you wish to hear 50 or 100 kms away and so is effectively blocked.

With analogue AM or FM if you are bored of your local radio station chances are that you can tune into an alternative distant radio station (given a suitable aerial) since it is likely to be on a completely different frequency to your own local station, this is often not so with DAB.

For Fun

Chances are that if you live in the Midlands you could tune into local stations in Manchester or London or other areas. This can sometimes be because you want to hear the programme material being broadcast on a different distant station and often because it is just great fun to pluck a weak and interesting station out of the ether.

A "Listening Post" Including HF Receiver and Scanner for VHF & UHF
[Click on the picture to see some more ideas about aerials on the Lowe HF-150 page!]

What do you need for long distance reception - DX-ing?

Medium Wave & Long Wave DX-ing:

Nothing too special is initially required, though as you become absorbed into the hobby bigger aerials and a better radio may be desired, but to start off with just a reasonable quality portable radio from a good radio name such as Roberts, Sony Grundig, Sangean or Panasonic may be all that is required to pick up very distant medium wave and long wave radio stations. A decent portable mw/lw/fm radio will cost about £30-£40 and will allow long distance reception especially on medium wave.

You **will** also require an aerial suitable for distant reception, the best, easiest and smallest being a LOOP AERIAL. See the page Loop Aerials and ATU's for details on how to make a simple Loop Aerial that will allow some good DX-ing even with a modest portable radio.

Eventually as listeners become more involved in the DX hobby a better communications receiver may be desired, such as a Palstar R30 or AOR AR7030. A long wire aerial can be employed, strung around a loft or down a garden to grab those really weak and far-flung stations, and a bigger and better directional loop aerial could be made. Again see the LOOP AERIALS and ATUs pages.

VHF / FM DX-ing:

If you also want to get into VHF/FM (Band 2) DX-ing from 87.5 MHz to 108 MHz then it is handy if the radio you use has an external aerial socket so you can connect an external *DIPOLE AERIAL* or *YAGI* that can be positioned in a loft or preferably outside. Even better will be to obtain a 4 or 5 element VHF *Yagi* aerial mounted on a rotator outside so that it can be electrically moved and pointed into any desired direction. During good reception conditions such as 'Tropospheric Lift or Ducting' and 'Sporadic E' that occur periodically during the year reception of stations at unimaginable distances can be experienced.

An external aerial can often be plugged into a portable radio that is fitted with a suitable socket and can offer surprisingly good results. A hi-fi system that includes a good quality VHF / FM tuner can be used to obtain some great 'DX' during the good 'lift' conditions when connected to a quality external aerial. It is important that the tuner has quite narrow IF filters to separate out the crowded stations, and some tuners offer different IF filter settings, so when DXing always choose the narrowest one. Check in the instruction book. The quality of tuners is quite variable, the 'separates' hi-fi tuners are usually very good, whereas the tuners that are built into a mini or midi stereo system or 'music centre' can often be quite poor, being noisy, insensitive and having wide IF filters that give poor selectivity - some are surprisingly good, however, so it's always worth a try.

During periods of good reception it is often possible to hear transmitters and local radio stations from hundreds of miles away and even European stations can be received at such high strength that the RDS (Radio Data System) information is decoded and displayed on those tuners that have the RDS facility.

A high quality Sony STSA50ES Tuner

Other VHF and UHF frequencies:

A scanner, such as the one seen in the picture of the 'listening post' above, will provide reception of frequencies above the Short Wave bands right through the VHF (Band 2) broadcasting bands and beyond - right up to UHF (Ultra High Frequencies). The actual frequencies that a scanners will cover depends upon the model, but frequencies from approximately 25 MHz (the top of the short waves) to 1300 MHz are typical. Some scanners offer this in one continuous band, but others omit certain small ranges - so check that the scanner you intend to obtain includes the frequencies that you wish to monitor!

This wide range of frequencies can enable monitoring of Amateur Radio Operators and other utility services using Narrow Band FM (n.b.f.m.) and sometimes narrow AM modes of transmission. The newer encrypted digital modes of transmission will not be heard as anything other than a 'mush', it must be noted.

The scanner can continually monitor a set range of frequencies - scanning through the range every few seconds. Alternatively a hundred, and usually many more memories are provided to memorise the favourite or most frequently used frequencies. The scanner can then be set to scan all or some of these memories only stopping on a memory channel when the frequency is active and a signal received.

A scanner requires a specialist aerial that can cover the enormous range of frequencies - a DISCONE is the most popular choice and is arguably the most effective, although there are alternative aerials available - both passive and active. Some of the alternatives look like white plastic sticks and these have the aerial elements inside, some include an active remotely powered wideband RF amplifier - these are known as Active Aerials. Active aerials work well when the listener is away from a town or main conurbation, but can be easily overloaded if situated near to an active transmitter of which there will be many in a town or city. It is often best, therefore, to use a passive type unless signal strengths are particularly weak in the area where the scanner is located.

SHORT WAVES:

Short Wave Reception - And more about the radios

Tuning to Short-Wave can reveal many stations from all around the globe. Many of the stations heard will be

from International broadcasters wishing to make their own country's views heard the world over. Additionally Amateur Radio operators can be heard chatting on the short wave bands, which can often prove very enlightening, especially if you are after some technical tips.

AOR AR7030

The short waves range from 3000 kHz to 30,000 kHz are used since they are reflected off a layer in the earth's atmosphere known as the Ionosphere. The ionosphere lies at a height of between 50 and 400 miles above the surface of the earth. This means that signals that may have otherwise been lost as they travelled straight out into space are reflected by the ionosphere back down to earth many hundreds, if not thousands of miles away from the transmitter site for distant audiences to tune into.

Sometimes high frequency radio signals can be bounced several times through the ionosphere before returning to earth, or even bounced back off the surface of the earth and again off the ionosphere to enable reception on the opposite side of the globe.

There are portions of the short wave band that are reserved for broadcasting and these are usually referred to as the short wave bands. eg 49meter band (6MHz) , 41meter band (7MHz) and 31meter band (9MHz). See "*THE BANDS*" table below. Some of more inexpensive 'dial and pointer' analogue radios tend to separate these into distinct switchable ranges, missing out the wavelengths in between. Digitally tuned radios may cover everything from 4MHz to 26MHz continuously without switching, many cover everything from 1.6 MHz right up to the top of the band at 30 MHz without missing out any frequencies.

Not all of the short wave band is used for 'broadcasting' programmes. There are many frequencies in between these broadcast bands that have, in the past, been used for 'Utility' stations which carried Morse Code, FAX, RTTY (Radio Teletype) from newsagencies and other modes of transmission such as AMTOR. These all make strange beeping noises but can be decoded with special hardware decoders or by using software on a PC. Have a look in Short Wave Magazine for more details. Much of this utility traffic has gone now, replaced by internet, computer and satellite. However there is still much voice traffic.

Much of the voice traffic will be from military sources - army, RAF, USAF and Navy - and from commercial aircraft and shipping and from coastguard and rescue services. If you refer again to THE BANDS table below you will see that Amateur Radio operators have specifically designated band on which they are allowed to operate, these bands are often buzzing with conversation. Remember that in general most of these voice transmissions will be in Single Sideband mode (SSB). And as a rule of thumb the frequencies below 10MHz (10,000KHz) use Lower Sideband, while the frequencies above 10 MHz use Upper Sideband (USB). You may sometimes have to listen for a while before hearing anything as not all the frequencies are active all the time.

Have a look at the SOME INTERESTING FREQUENCIES notes at the bottom of this page for some ideas of where to tune into.

Why do some frequencies appear to be completely dead?

As a very rough guide, and from my own experience, frequencies between 12MHz to 30MHz work better during daylight hours, due to the way the ionosphere propagates the radio waves. During the night they will usually seem very quiet or completely dead - especially as the broadcasters, knowing that propagation at this time will be very poor they will switch their transmitters to other frequencies.

At night time frequencies below 12MHz tend to be propagated more effectively by the earth's ionosphere, so broadcasters will use these more extensively during darkness and they will usually appear to be very active at night. The 49 meter band (6MHz) and the 41 meter band (7MHz) are usually the best, though the 75 meter band (4MHz) and 31 meter band (9MHz) are often good night time choices too.

More about radios:

To obtain the short wave bands a slightly more expensive radio than the average mw/lw/fm portable will be

required. Some inexpensive portable analogue (dial and pointer) radios offer one additional short wave band, usually the 49 meter band, that will enable reception of many of the main international broadcasts from around the globe on a simple telescopic aerial and this can be a good introduction to the world of short wave. For the more ambitious a dedicated short-wave / world-band portable, such as those pictured at the top of this page will be more desirable, and indeed necessary if you wish to tune into the SSB transmissions.

So, moving up the radio market a little there is a good choice of digitally tuned portables that offer very accurate tuning and much wider and continuous coverage of the short wave bands. Again a radio from a good manufacturer will be needed for satisfactory results, as the very cheap radios that are often labelled '*world band*' that can be seen on offer in discount stores or your local market will prove very unsatisfactory as they are poorly designed being very un-selective meaning that they cannot adequately separate one station from another on the crowded short wave bands.

These cheap radios can be had for as little as £20 but will also prove to have very inaccurate tuning dials, so you just won't know to what frequency you are tuned. They are often insensitive which will mean that the weaker stations will not be heard and always suffer from a poor image rejection ratio which manifests itself as stations appearing not only at the intended position on the dial but also at several other positions causing much unwanted interference and noise.

The best bet for an introduction to good short wave reception is to buy a portable radio manufactured especially for the purpose which uses a digital readout for accurate tuning so you always know to which frequency the set is tuned along with continuous coverage of short wave. Popular manufacturers for such sets are **Sony** (eg ICF-SW35 or ICF-SW7600), **Roberts** (eg R9921, R881 or R861), **Grundig** (eg YB400 or Satellite 800) and **Sangean** (eg ATS 404 and ATS 909). See O'Gormans Radio>> for some examples.

The higher specification, and therefore more expensive, **communication receivers** that are dedicated to mw/lw and sw are produced by Palstar (i.e. R30), AOR (i.e. AR7030), ICOM, KENWOOD and YAESU (FRG-100) amongst others.

Vintage Grundig Satellit multi-band radio

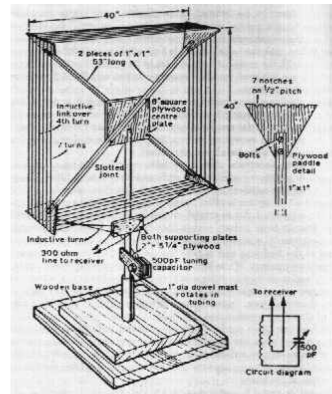
AERIALS:

No matter how good your radio it must be fed by a good antenna!!

For Medium Wave and Long Wave

Portable Medium Wave Loop

Long Wave Frame Aerial



Constructional Diagram

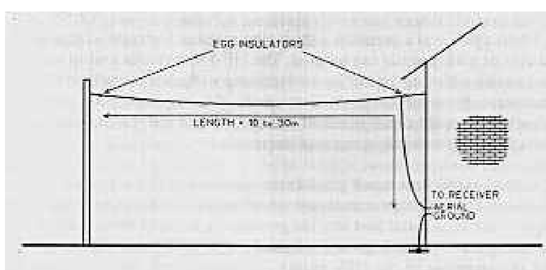
The most effective aerial for medium-wave and long-wave DX-ing is probably a loop aerial >>. A loop aerial is useful because it is often easier to use than having to string up a large long-wire outdoor aerial. A loop aerial is very discriminatory in that it is both *Directional* and *Selective*. The directionality can help null out unwanted interfering stations and the selectivity prevents overloading of the radio because the loop is tuned into the frequency of the desired station, rejecting all others. A long wire aerial can easily overload the tuning circuits of a radio and the directional and selective characteristics of a loop avoid this.

When I constructed my first medium wave loop aerial I was utterly amazed at its performance - pulling in stations that I had never heard previously. I still think, even considering its simplicity, that the loop aerial is best piece of equipment I have ever made!

Traditionally such an aerial is wound around a large wooden frame often 100cm x 100cm and connected directly to a receiver using the external aerial socket. A typical example is seen in the centre photograph above.

For portability and for effective use with a portable radio a smaller loop can be constructed so that a typical portable radio can sit in comfortably in the centre and the signals received by the loop aerial coupled to the radio's internal ferrite rod aerial.

An Aerial For Short Wave



Random Wire Aerial

[Click on the picture to see some more ideas about aerials on the Lowe HF-150 page!]

To obtain good short wave reception it is absolutely essential to have a large enough aerial placed as high as is practical and positioned as far away from any sources of electrical interference as possible.

The easiest and therefore most common aerial for short-wave reception is simply a length of wire suspended as high as possible and as far as possible, often referred to as a 'long wire', it is more correctly termed a '*Random Wire*' since its length is not cut to be resonant with any particular wavelength. A random wire may be 10 to 30 meters long and be strung around the loft or down a garden slung from poles or trees, or even around all four walls of the listening room. (This long random wire aerial can also be used for medium and long wave reception - though I still prefer to use a loop aerial for these bands.)

For portable radios:

This random wire aerial could be connected directly to the receiver's aerial socket if it has one. If the radio has no aerial socket then the aerial could be clipped directly onto the telescopic rod with a crocodile clip, but both of these options could overload a portable radio's tuning circuits and while not harmful it will cause much undesired noise and interference.

It is usually much more effective to indirectly couple the aerial to the radio: Wind the last few centimetres of aerial wire into about 6 to 20 turns around a paper tube and slide this over the telescopic aerial and adjust its position along the rod until the best signal coupling is found. Sometimes even better results are obtained by connecting the free end of the wire to earth.

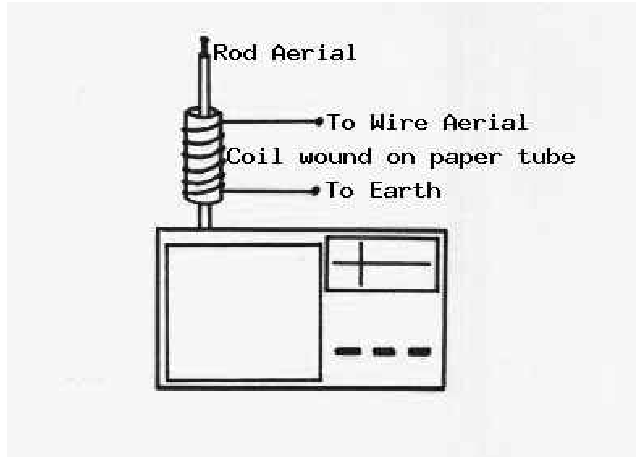


Illustration shows a method of coupling a wire aerial to a radio with no aerial socket.

A better option is to connect the aerial to a portable radio's antenna socket via an ATU - see below

If a communications receiver is being used then the long random wire aerial can often be connected directly to the set's antenna terminals, as many receivers of this type can handle the strong signals present. Even better is the use of an ATU (Antenna Tuning Unit) as this will help with better signal transfer:

ATU's (Antenna Tuning Units)

Connecting a long aerial directly to the telescopic aerial of a portable radio, in particular, can cause serious overloading of the radio's '*front end*' (the tuning circuits) producing lots of unwanted noise and interference.

An Aerial Tuning Unit

A better method of coupling a long *random wire* aerial to a short wave radio that has an antenna socket is to use an Antenna Tuning Unit that also incorporates an attenuator to reduce the signal if neccesary. An ATU can help match the widely varying impedence of a random length of wire to the fixed 50 ohm impedence present at the input of the radio. By better matching the aerial to the radio more of the signal collected by the aerial will be transferred to the radio.

However should reception conditions be very good and signal strengths are very high then too much signal could swamp the radio's tuning circuits. In this case an *attenuator* will be very useful, giving the ability to gradually reduce the incoming signal. A simple attenuator consists of a variable 1k resistor which can be incorporated into the ATU circuit.

For more information on LOOPS, AERIALS and ATU's and some useful circuits have a look at the LOOP AERIALS and ATUs >> page.

THE BANDS:

Short Wave:

INTERNATIONAL BROADCAST HF BANDS			AMATEUR HF BANDS	

Meter Band	Frequency (MHz)		Meter Band	Frequency (MHz)
120	2.30 - 2.495 'Tropical Band'		160 ("Top")	1.80 - 2.00
90	3.20 - 3.40 'Tropical Band'		80	3.50 - 3.80
75	3.90 - 4.00 Europe, Asia, Africa		40	7.00 - 7.20
60	4.750 - 5.060 'Tropical Band'		30	10.10 - 10.15
49	5.800 - 6.200		20	14.00 - 14.35
41	7.200 - 7.450		17	18.068 - 18.168
31 - heavy use	9.400 - 9.990		15	21.00 - 21.45
25	11.60 - 12.10		12	24.89 - 24.99
21	13.57 - 13.87		(CB Radio)	26.96 - 27.99
19	15.10 - 15.80		10	28.00 - 29.70
16	17.48 - 17.90			
15 - rarely used	18.90 - 19.02			
13	21.45 - 21.85			
11 - DRM?	25.60 - 26.10			

(N.B. 1000kHz = 1MHz)

Link : Find Short Wave Stations and Frequencies at - http://www.shortwaveschedule.com/

Domestic Broadcasting:

DOMESTIC BROADCAST BANDS				
Band / Use	Frequency (MHz)		Band / Use	Frequency (MHz)
Long Wave / AM Radio	0.15 - 0.28		Band III Television (Not UK)	175 - 210
Medium Wave / AM Radio	0.51 - 1.62		DAB / Digital Radio	209 - 216
Band I / Television (not UK)	48 - 67		Band IV and Band V / Television	470 - 860
Band II VHF / FM Radio	87.5 - 108			

SIGNAL METER CALIBRATION:

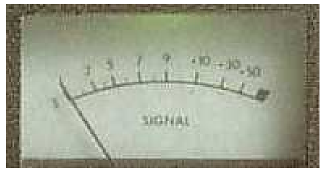
Signal Meters on H.F. Communications Receivers: often have signal meters marked 1 to 9 followed by decibel readings, the chart below provides a conversion to the terminated voltage (in microvolts) at the radio receiver:

Signal	1	2	3	4	5	6	7	8	9	9 +10dB	9 +20dB	9 +30dB	9 +40dB	9 +50dB
uVolts	0.2	0.4	0.8	1.6	3.2	6.3	12.5	25	50	158	500	1580	5000	15.8mV

Note how relatively small changes in voltage at the lower end of the scale (in the S1 to S8 range) produce quite noticeable swings in the readings, while really quite large changes in signal voltage at the higher end of the scale

(S9 to S+50) produce quite small variations in read-out. This non-linear effect is quite intentional: Increases in signal strength from S1 to S9 will produce dramatic improvements in the received signal to noise (S/N) radio while above around the S9+10dB signal level the receiver is approaching the best achievable S/N ratio and further large increases in signal strength will make less if any improvement to the audible S/N ratio, so the S Meter does not really need to reflect these changes in such minute detail.

The signal meter is invaluable when making aerial adjustments and comaprisons as well as being useful for comparing the strength of various transmissions.



See also: How To Make A Signal Meter

RECEPTION REPORTING using the S I O code:
With reference to a signal meter on a typical communications receiver, the table below plots the indicated signal strength against the correct reporting code.

S = The Signal Level **I** = The amount of interference **O** = The (rather subjective) overall quality of the signal. The S and the I parts are indicated below:

Signal shown on meter	S as reported in the SIO code	Amount of Interference	I as reported in the SIO code
1 to 3 (v. weak to weak)	**1**	**Extreme**	**1**
4 to 7 (fair to good)	**2**	**Severe**	**2**
8 to 9 +10 (strong to very strong)	**3**	**Moderate**	**3**
9 +20 to 9 +30dB (very strong)	**4**	**Slight**	**4**
9+40 to 9+60dB (extremely strong)	**5**	**None**	**5**

O (Overall Quality) is then given as: **5** = Excellent **4** = Good **3** = Fair **2** = Poor **1** = Very Poor almost unreadable

THE S I N P O CODE:

The SINPO code adds a little more detail by including values for N = Noise and P = Propagation Disturbance.

Signal Meters on Hi Fi Tuners: Often some older analogue hi-fi radio tuners included a swinging needle type signal meter to aid tuning on VHF / FM stations. These basic meters provided a rough guide to signal strength, but from experience of various hi-fi tuners that I have used over time the chart below can give some idea of the actual terminated voltage at the tuner's aerial input. The chart below gives a rough approximation:

SIGNAL METER READING (vhf / fm)	**1**	**2**	**3**	**4**	**5**
Microvolts (approximate)	**5 - 10**	**10 - 20**	**30 - 80**	**160 - 250**	**500-1000**

Required Signal Strength For Acceptable FM Stereo Reception: A top quality HiFi FM tuner will often produce a signal to noise ratio of 60 dB when receiving about 200 microvolts, less than this and reception will be unacceptably noisy. So a deflection on the signal meter of 4 or above is really needed for good stereo. A

reading of less than 4 will normally indicate that the tuner should be switched to mono for less noisy reception this is because FM stereo requires up to ten times more signal strength than mono reception to obtain the same signal to noise ratio. To obtain full quieting of around 70 dB, i.e. the best signal to noise ratio, most good tuners would need 300 to 500 microvolts and cheaper tuners and average all in one stereo micro and mini systems etc may need even more than this if little attention has been paid to the tuner circuits. [NB CD audio can achieve 90 - 100 dB signal to noise ratio.]

Signal Meters on Hi Fi Tuners With digital dB (Decibels) Read-out: Some Hi-Fi tuners, Sony is one example, have a signal strength read out in dB and while total accuracy cannot be guaranteed, this type of indication will be much more useful than a swinging needle or five LEDs. This readout will give an indication of the Terminated Voltage. To convert the dB figure given in the readout to the actual voltage you will need to use the table shown below:

Download an Information Sheet here : dB_power_and_voltage_information_sheet_MDS975.doc

Decibels to microvolts conversion

VOLTAGE dB = 20 x Log of Voltage
(e.g. 20 x Log of 158uV = 44 dB)

...and therefore;

VOLTAGE µV = Antilog of Voltage dB ÷ 20
(e.g. Antilog of 45 ÷ 20 = 178µV)

Notice that every 6db increment is equivalent to a doubling (or halving) of voltage, and that every 20dB increment is equivalent to a x 10 increase (or a ÷ 10 decrease) of voltage.

(The table below shows results that are reference to 1 microvolt **)

dB	2	3	4	6	8	10	12	14	16	18	20	22	24
uV	1.25	1.4	1.6	2	2.5	3.2	4	5	6.4	8	10	12.5	16
dB	26	28	30	32	34	36	38	40	42	44	46	48	50
uV	20	25	32	40	50	64	80	100	125	158	200	250	318
dB	52	54	56	58	60	62	64	66	68	70	72	74	76
uV	398	500	630	794	1000	1260	1580	2000	2500	3200	4000	5000	6400

Here's a more comprehensive table:

dB	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
µV	1.12	1.25	1.4	1.6	1.8	2	2.2	2.5	2.8	3.2	3.5	4	4.5	5	5.6
dB	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
µV	6.4	7.07	8	8.9	10	11.2	12.6	14.1	15.8	17.8	20	22.4	25	28.2	32
dB	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
µV	35.5	40	44.7	50	56.2	64	70.8	80	89.1	100	112	125	141	158	178
dB	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
µV	200	224	250	282	318	355	398	447	501	562	630	708	794	891	1000
dB	61	62	63	64	65	66	67	68	69	70	72	74	76	78	80
µV	1122	1260	1412	1580	1778	2000	2239	2500	2819	3200	3981	5011	6400	7943	10mV

A Note About Calculating Field Strength: If you wish to know the actual field strength in dBuV/m at the point where the aerial is situated you will need to add in some other factors:

Feeder Loss in dB: e.g. a certain type of 75 Ohm coaxial aerial cable my have a loss of 10dB per 100 metres, so if your aerial installation uses 10 meters of coaxial cable then you will have to factor in a 1dB loss.

Aerial Gain in dB: A simple dipole may be considered to have zero gain i.e. 0dB, a three element *Yagi* aerial may have 3dB gain whereas an omnidirectional horizontal circle type aerial could be considered to have minus gain - e.g. -3dB. This figure needs to be taken into account.

Termination Loss: Can usually be assumed to be 6dB

Effective Length: Usually assumed to be 0dB

Example: The terminated voltage at the tuner is 500uV (Log 500 x 20 =54dB) so the field strength when using an aerial with 3dB gain is:

54dB Terminated Voltage -3dB Ae Gain + 0dB Eff Length + 6dB Term Loss + 1dB Down-lead Loss = 58dB Field Strength

(i.e. The field strength where the aerial is sited is approximately 794 uV, so there has been a 294 uV loss in the receive aerial system.)

TRANSMITTER POWERS

The signals that our radios receive originate from the radio station's RF (radio frequency) Transmitters, so lets have a quick look at the power used by typical stations and how it's expressed.

A very small scale, localised community station by be in the order of 1 watt to 50 watts. Typical local radio stations or small scale local relay transmitters my be in the order of 10 watts to 1000 watts. Larger "local" and "regional" stations relay transmitters my be in the order of 1000 watts (1kW) to 25,000 watts (25kW). Large transmitting stations used by national broadcasters may have transmitter powers of 20,000 watts (20kW) to 300,000 watts (300kW). Often the antenna used will be directional, so the power quoted will be the maximum "Effective Radiated Power" (E.R.P.), therefore the effective power in some directions will be somewhat less - sometimes significantly less when transmitters using the same frequency in other geographical regions need to be protected from interference.

City stations in the USA and Canada will often use transmitters with a transmitter power of around 5,000 watts (5kW) to 50,000 watts (50kW). 50,000 watts is the maximum power allowable in these countries and often referred to as power-house stations. Small scale stations will, of course, often use less power than this.

For international broadcasting, transmitter powers of anything between 50,000 watts (50kW) and 2,000,000 watts (2MW) could be used. It would be quite usual to fine international short wave (H.F.) transmitters with powers of 100,000 watts and 500,000 watts.

The figures quoted above are a broad generalisation. Exact specifications are often available from regulators such as Ofcom in the UK and the FCC in the USA, for example. Other great sources are available, such as the "WRTH" for international information and the Radio Listener's Guide for listeners in the UK.

Often transmitter powers are quoted in Watts or Kilowatts, but sometimes the dBW figure is used. The information below shows the conversion between dBW and watts.

Links:
WRTH - http://www.wrth.com/
Radio Listener's Guide - http://radioguide.co.uk/
FCC - https://www.fcc.gov/media/radio/am-query https://www.fcc.gov/media/radio/fm-query
RadioLocator - find information and coverage maps - http://radio-locator.com/
Ofcom - http://stakeholders.ofcom.org.uk/broadcasting/guidance/tech-guidance/tech_parameters/ & http://www.ofcom.org.uk/static/radiolicensing/mcamaps/MCAs.htm

TRANSMITTER OUTPUT POWER SCALE - dBW and Watts

DBW

Notice that when dealing with Voltage a 6dB increase represents a doubling of the voltage, whereas when dealing with Power a 3dB increase represents a doubling of power and a 10dB increase represents a multiplication factor of 10, as can be seen in the table below:

Transmitter powers are usually quoted in Watts, but occasionally they are given in dBW (reference to 1 Watt **). The chart below converts dBW figures to Watts.

dBW	0	1	2	3	4	5	6	7	8	9	10	20	30	40	50
Watts	1.0	1.25	1.6	2.0	2.5	3.2	4.0	5.0	6.4	8.0	10	100	1kW	10kW	100kW

[For example if a radio station quotes a transmitter output of 38 dBW just multiply the 30dBW figure (i.e. 1kW) by the 8dBW figure (i.e. 6.4): 1kW x 6.4 = 6.4 kW or if the quoted power is 49 dBW then 10kW x 8 = 80 kW]

POWER dBW = 10 x Log of Power
(e.g. 10 x Log of 1995 watts = 33dBw)

and therefore;

POWER (watts) = Antilog of Power dBw ÷ 10
(e.g. Antilog of 14dB ÷ 10 = 25.11 watts)

DBM

dBm	1	10	20	30	40	50	60
milliwatts	1	10 (0.01 watt)	100 (0.1 watt)	1,000 (1 watt)	10,000 (10 watts)	100,000 (100 watts)	1,000,000 (1 kW)

Example calculation (provided by Mark Timlin):

To find the power in milliwatts for a dBm figure of 62:

62 divide by 10 = 6.2

Antilog 6.2 = 1584893 milliwatts

1584893 x 0.001 = 1584.8 watts

N.B. **The Decibel measurement is purely a **ratio**, it is not an absolute power or voltage. For a decibel reading to be meaningful it must be referenced to a certain voltage or power. If we know that the Decibel measurements are reference to 1 Volt (for example) then we know that 0 dB = 1 Volt and so we therefore can calculate that 6dB = 2 Volts and that 20dB = 10 Volts etc.

Similarly with power, if the dB readings are reference to 1 Watt (for example), then we know that 0dB = 1 Watt and therefore that 6dB = 4 Watts and 20 dB = 100 Watts etc.

Download an Information Sheet [here : dB_power_and_voltage_information_sheet_MDS975.doc]

Panasonic RF-3100 Short Wave H.F. Antenna Installation and Propagation Advice:

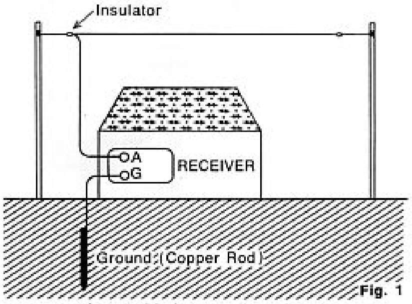


Fig. 1
Inverted-L Antenna (Long Wire)

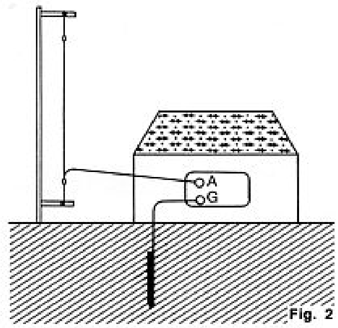


Fig. 2
Vertical Antenna (Long Wire)

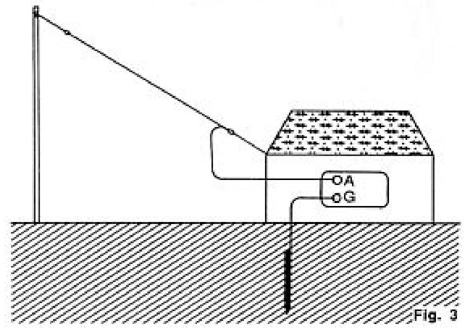


Fig. 3
Slant Antenna (Long Wire)

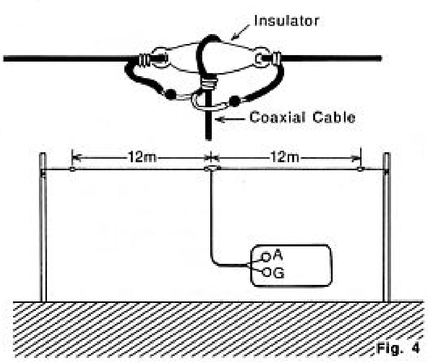


Fig. 4
Doublet Antenna

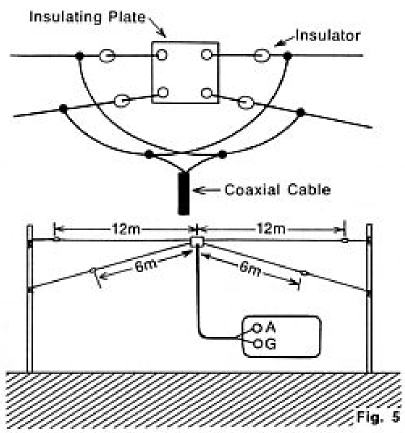


Fig. 5
All-Wave Antenna

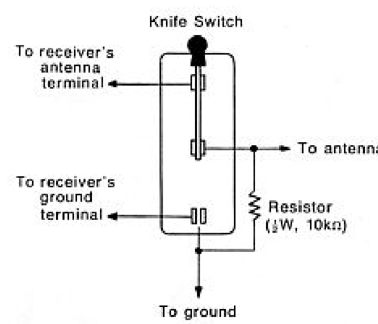


Fig. 6

Single-Sideband (SSB) and Continuous Waves (CW)

Single-Sideband (SSB)

In general, SSB corresponds to a modulated wave in the AM Double-Sideband (DSB) signal. It is used for business purposes and amateur radio, and it can be regarded as a special type of AM wave.

Features:

1) In case of transmitting: All information is transmitted with a little energy and bandwidth.
2) In case of receiving: Since there is no carrier, it is necessary to use a special detection method.

AM (DSB) waves can be illustrated in a spectrum as in Fig. 7.

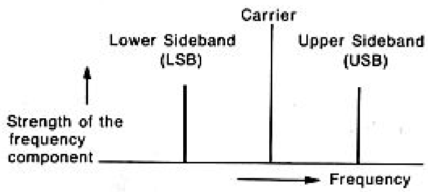


Fig. 7

Electromagnetic waves (carrier and both sidebands) are transmitted as a single group in an AM form. The sidebands are the Upper Sideband (USB), higher than the carrier frequency and the Lower sideband (LSB), lower than the carrier frequency.

Voice and other information is contained in the sidebands but not in the carrier; thus the carrier is not always necessary, and so other methods for transmitting the information can be considered.

One of these methods is SSB. Either the USB signal or the LSB signal is transmitted and it depends upon individual circumstances. Usually for amateur communication, LSB is used under 10 MHz and USB used over 10 MHz. SSB waves are generated by passing the AM wave through a band-pass filter, then selecting either USB or LSB and sending the signal through the transmitting antenna. In receiving SSB (USB or LSB) waves on an ordinary AM receiver, it is not possible to hear a transmitted voice unless a special alteration is made at the detection stage. It is possible either to construct the carrier and detect the AM after adding the SSB or to use the switching method (product detection) on the frequency of the carrier for the SSB. The latter method has less distortion, and it is used in this unit.

Continuous Waves (CW)

In practice, these are used to transmit Morse code signals by intermitting the carrier, but it is difficult to hear the sound even after AM detection. Using the detection circuit of the SSB, the intermittent sound can be heard by product-detecting the carrier and by varying the frequency a little.

Propagation of Electromagnetic Waves

Electromagnetic waves of a broadcast are separated into surface waves which are propagated along the surface of the earth and space waves which are propagated upwards. Low frequency waves (LW & MW) are surface waves, while high frequency waves (SW) are bounced off the ionosphere which is located 100~300 km above the earth's surface. This is charged and acts like a mirror toward electromagnetic waves. That is why high frequency waves can be received over great distances. On the other hand, the electromagnetic waves of higher frequencies (VHF) extend beyond the ionosphere and can only be used for short distances.

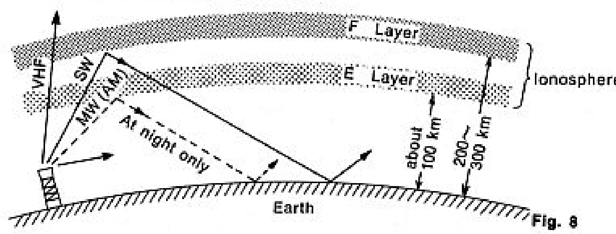


Fig. 8

The ionosphere is considered a product of the sun's ultra voilet rays, and consequently, the conditions of the ionosphere change from time to time due to the position of the sun. Seasonal variations also occur. Since it is multilayered, the path of propagation of electromagnetic waves is extremely complex.

In particular, the number of solar spots changes every 11 years, and this change affects the shape of the propagation. In receiving SW broadcast, all the foregoing must be kept in mind. Most best known SW stations take all these factors into consideration and change the frequency from season to season or broadcast with two or more different frequencies at the same time for optimum reception.

Features of the Meter Bands and Amateur Bands

Meter Bands

120m (2.3~2.495 MHz) and 90m (3.2~3.4 MHz) Bands
These two bands are used solely in tropical regions where unusual electrical activity and other types of noise make MW (AM) reception impractical. They are used mainly for local broadcasting. In comparison with MW (AM), they are rather difficult to receive because of noise or intermittent signals.

75m Band (3.9~4.0 MHz)
This band is used for short-distance broadcasting in tropical regions.

60m Band (4.75~5.06 MHz)
This band is like the 120m and 90m bands and is used chiefly for local broadcasts in tropical regions.

49m Band (5.95~6.2 MHz)
This band is mainly used for short and medium-distance international broadcasts and local broadcasts. Depending on the season, and since international broadcasts use this frequency instead of high frequencies, it is possible to receive broadcasts from many countries.

41m Band (7.1~7.3 MHz)
The propagation of this wave is similar to that of the 49m band. It is chiefly used for medium to short-distance broadcasting.

31m Band (9.5~9.775 MHz)
Heavily used for international as well as local broadcasts. Short Wave broadcasts of different countries are transmitted in this band, and if the receiving conditions are favorable, it is possible to receive many stations at every 5 kHz.

25m Band (11.7~11.975 MHz)
The propagation of this wave is similar to that of the 31m band, and follows the 31m band in popularity because many international broadcasting stations with strong output signals use this band throughout the year.

19m Band (15.1~15.45 MHz)
This is chiefly used by international broadcasting stations and is regarded as the "Main band." From this band to the higher frequency bands, reception becomes difficult as the number of solar spots decreases.

16m Band (17.7~17.9 MHz)
This is used by international stations for purposes similar to the 19m band, but because it is greatly affected by any slight change in the solar spots and in different seasons, reception is often impossible. If stations are received at all, they are surprisingly similar to strong signal stations.

13m Band (21.45~21.75 MHz)
This band is used for long-distance international broadcasts. It is used regardless of the seasons when the solar spots are active. Condition of this band changes from time to time.

11m Band (25.6~26.1 MHz)
This band is used for long-distance international broadcasts during heavy activity in the solar spots. Like the 13m band, its condition changes from time to time. When the conditions are good, reception is easy as there is neither noise nor interfering signals.

Amateur Bands

160m Band (1.9 MHz)
This band is also called the "Top band", and among amateur bands it has the longest wave length. Though it is good for short-distance transmissions, many ham fans prefer it for DX communication.

80m Band (3.5 MHz)
This band is generally used for short-distance broadcast. However, depending on the season and time, it can be used for DX traffic communication.

40m Band (7 MHz)
When the solar spots are least active, this band is most efficient for DX communications. However, its allotted bandwidth is narrow and it is susceptible to interfering signals.

20m Band (14 MHz)
Also called the "Amateurs' main band". Its listening area changes with the time and the season. It can be used as a world-wide traffic communication band, and it is usually possible to receive broadcasts from every country.

15m Band (21 MHz)
When the solar spots decrease, DX station and traffic communication signals are difficult to receive. When the spots are active, it is possible to receive low-power DX stations as surprisingly strong signals.

10m Band (28 MHz)
Among amateur bands, this has one of the higher frequencies (HF). This band has both HF and VHF characteristics, and has more features than 15m band; when the solar spots are active, you can tune into very distant DX stations.

Verification Card

Short wave broadcasting stations usually issue a verification card for listener's reception reports. At the same time, broadcasting timetables and various pamphlets are supplied to listeners, making it easy to plan a reception schedule and note changes in frequencies, etc.. To get a verification card, a correct reception report should be sent to the broadcasting station. The method of writing a reception report is as follows:
Using the broadcast country's language is most desirable, but English can usually be used, and the report should be written in simple sentences. Make sure you write all of the information useful to the station. When filing, the following items are the minimum requirement.

1. Name of the station.
2. Date and time of reception (GMT indication).
3. Frequency.
4. Signal receiving conditions. The conditions can be expressed in numbers by referring to the SINPO code shown on page 6.
   However, it is also advisable to explain them in writing.
5. Reception area and your name and address.
6. Reception equipment: Type of radio, antennas, etc..

Send this information to the broadcasting station. If you send the report frequently to the same station, that station will return information regarding frequency and program changes to enable you to program your time for up-to-date reception.
You may find that only the name of the country and the city of the station are announced over the air, so if you don't receive the verification card, keep sending reports until you do. Of course, you can send to as many stations as you wish. The cards sent from various countries show local landscape and culture which enrich your knowledge of foreign lands, and will also increase your enjoyment of listening to the radio broadcasts.

GMT

Is an abbreviation for Greenwich Mean Time. Almost all international broadcasts express time according to GMT.

(SAMPLE REPORT)

Your Address
Your Name
Date

Radio Japan
Tokyo Japan

Gentlemen:
I listened to you on Mar. 10th, 1977, from 1500 until 1600 GMT on approximately 15255 kHz.
Received programs and receiving conditions were as follows:

TIME (GMT)	PROGRAMS
1500	Opening announcement in Japanese & English (by male announcer)
1502-1515	News in English (by male announcer)
1515-1530	News commentary (by male announcer)
1530-1558	Folk music
1558-1600	Closing announcement in Japanese (by female announcer)
SIGNAL STRENGTH:	(4) good
INTERFERENCE:	(4) slight (telegram)
NOISE:	(5) nil
PROPAGATION DISTURBANCE:	(5) nil
OVERALL RATING:	(4) good
RECEIVER:	Panasonic Radio Model No. RF-2800 (FM/AM/SW 5-band portable radio receiver)
ANTENNA:	Inverted-L type (8 meters high, 12 meters long)
REMARKS:	

Please send me your verification card if this report is correct.

Yours truly,
Your Name

〈SINPO TABLE〉

	Signal Strength	Interference	Noise	Propagation Disturbance	Overall Rating
	S	I	N	P	O
5	Very strong	None	None	None	Excellent
4	Strong	Faint	Faint	Faint	Good
3	Medium	Medium	Medium	Medium	Fair
2	Weak	Strong	Strong	Strong	Poor
1	Faint	Very strong	Very strong	Very strong	Unusable

Verification Cards

– 6 –

Above: Panasonic RF-3100 Short Wave H.F. Antenna Installation Advice

More Information:

Loop Aerial & ATU Constructional Pages - Make your own reception aids!

Lowe Electronics HF series of Communications receivers

Radio Stations & Memorabilia

Don't forget to read **Practical Wireless Magazine**, **Radio User Magazine** and join **The British DX Club** for great articles, reception tips and invaluable information.

Find Short Wave Stations and Frequencies at - http://www.shortwaveschedule.com/

Amateur Radio
MØMTJ Visit my amateur radio pages MØMTJ

Click to visit my amateur radio pages

My Amateur Radio Call Sign is MØMTJ

NUMBERS STATIONS

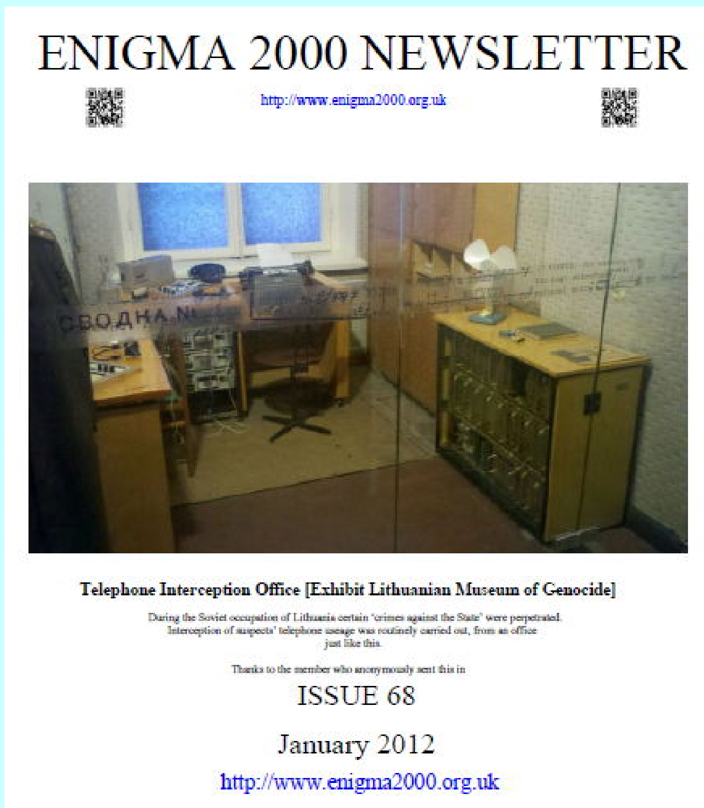
Emails from Gary Hagermann:

"Good Afternoon Mike,

Just a short email to express my appreciation of a very interesting site. I am a recently early retired radio enthusiast, having picked up radio as a ten year old, and now, at 65 years of age, I have to say it is getting b---dy heavy, but I still won't put it down.

My British Army tour of 1964 to 1971 as a Regular, and my Reserve Service of 1972 to 1984 saw me continue this interest, and all at someone else's expense! Neat, huh? I particularly enjoyed your clip on Number Stations [see below] as I belong to ENIGMA 2000, a Group which specializes in these and other Military and Intelligence related communications modes. They are still alive and well, although not so prolific as in recent years, the Cold War in particular.

They abound in CW (Morse), voice, and various data transmission modes. If you wish, I will send you a frequency prediction list which is produced by Ary Boender, one of our members. [Shown below]



Download a Sample Newsletter here
Visit Enigma 2000 for the latest news at the URL:
http://www.enigma2000.org.uk

I also enjoyed your various radio receiver reports. I have a Yaesu FRG 7700 with a long wire aerial into a FRT 7700 aerial tuner and FF5 notch filter. I use my desktop PC for recording, but it is daisy chained into a cassette recorder and a reel to reel tape recorder for off air recording. (I know, it sounds like Marconi's coffin in this shack!) I also have a Grundig Yacht Boy as a stand by and portable rig.

I am trying to bring an old R1155N back to life, but the Force is not as strong as once it was!

Well, some short email, but I did love the site, and will be back.

Very best wishes to you and the family, and Best DX.
73 de Gary."
[January 31st 2012]

Thanks for all the information Gary, it's all absolutely fascinating. Much appreciated, Mike

More from Gary.....

"Hello Mike,

Today I took delivery of my brand new Eton Satellit 750. Got it up and running in the shack as I type. Really does make the winter seem a bit more bearable. (Yeah, well, I know that is an exaggeration!)

Hope you get some joy with the number stations. The stations marked as X or XPA are data transmitters. One of the guys has written a program to decrypt it into numbers/letters, but as you know, decrypting the actual message is a complete no-hoper. We think the numbers and/or letters must be for one time pads or a derivative of them. A book code is possible, given the amount of literature is knocking about the world.

As an Intelligence Corps sergeant said to me; "Just because the message is sent in English, German or whatever, only proves the sender and receiver understand enough to send numbers/letters in that language." This was circa 1966 and all was black and white to me then! I had just said something like; "If this is a German message, must be for a German, huh Sarge?" Oh foolish youth!!

Let me know how you get on.

If you want some other frequencies, USAF have a worldwide HF net and 11175 USB is a good one to listen out on.

There are more, but my addled brain needs a book to refresh it! If you get a string of NATO phonetics, it is an EAM or emergency action message. Another one they send is "Skyking." Both are in the deepest of encryption, so no chance of cracking that either! Just as well, a lot of my family are American, and I have no wish to see the other side of Cuba! (As in Gitmo Bay!)

Best DX and 73 de Gary Hagermann"

Thanks again Gary! Best wishes, Mike.

PLAY The Audio: "The Numbers Stations" from BBC Radio Four (2005)

Visit - http://www.enigma2000.org.uk

My own Amateur Radio Pages can be seen here - MØMTJ

LONG WAVE RECEPTION OF BBC RADIO FOUR IN CENTRAL FRANCE

READERS QUERIES

Query One:

Hello, I found your website when I was trying to source information on how to make my old valve radio work more efficiently. It was my grandfather's and as it was in very good condition I took it with me to France where I live some of the year. I tune the radio in to the Long Wave to listen to BBC radio 4.The problem is that reception is very bad. Only occasionally do I hear the station clearly. Often there is fading and also every kind of crackle in the world drowns out the station. We are situated in the middle of France near Brive. Can I improve the reception? If I took an aerial out on to the roof would this help? Or am I trying to make an old radio work in conditions that are hopeless? I fully understand that I could buy a modern radio,(we have one). I can also at

any time listen to any station I want via satellite and on my laptop, but that isn't the point. I would like to receive the BBC on my old radio - which I may add, looks rather grand. If you would be kind enough to give me any advice I would appreciate it very much. Peter Laing Gillies.

Possible Aerial Solutions

Given a weak signal then there is always something that one can do to improve the situation with regard to a better and more efficient aerial arrangement.

If the radio set has an input for an external wire aerial then running a length of insulated wire, say 10 meters or so, outside should improve the strength of the signal. String the aerial wire around a garden or yard if possible, or suspend it from wooden poles fixed to either end of the house so that the wire is a meter or two above roof level.

One has to bear in mind that a big aerial can produce large signals from your nearby medium wave and long wave transmitters that may 'swamp' the radio's tuning circuits (RF overload) and produce more noise and different problems. It is worth a go though, and if there are no close by transmitters then an aerial of between 10m and 30 m could be tried. It is always worth experimenting with different aerial locations and orientations to find the best results.

However if you are suffering noise in the form of 'every kind of crackle' then obtaining good, or at least better reception can become a little more difficult. Generally a better aerial will not only improve the signal from the required radio station but also proportionately increase the strength of the interference sources. So you will still suffer with the interfering crackles.

If the source of the interference is within the house then connecting the aerial to the radio via screened, coaxial, cable may help reduce the amount of interference being delivered to the radio. This will only be of use if the radio has both aerial and earth connection terminals: (Beware of older valved radios - don't try connecting wires internally to the chassis - these radios often have a chassis that is at mains potential and serious electrical shock or death could result.)

Connect the inner, centre conductor of the cable to the aerial/antenna input of the radio and the outer braided conductor of the cable to the earth/ground terminal. Run the coaxial cable from the radio to a point outside the house/building several meters away from the boundary of the building. This keeps any interference originating from inside the house away from the aerial. Then connect 10m to 30m of pvc insulated wire to the centre conductor of the coaxial cable and place it high up away from the house. The outer braid of the coax cable can be connected to an earth stake a few feet long that has been driven into some damp soil - this may help take any interference picked-up inside the house on the braided part of the coaxial cable down to earth.

The use of an ATU may help with matching the aerial and coaxial feeder to the radio, as might the use of a matching transformer at the junction between the aerial wiore and its point of connection with the coaxial cable. See the ATU page HERE.

The other possibility is to use a large frame aerial. Make a frame aerial about 1meter square or larger if possible. The advantage of a frame aerial is that, although it does not pick up as much signal as a long wire aerial, it is very directional and can be rotated to either give the highest signal from the wanted station or to reduce to a minimum (null out) an interfering station or source of noise.

A frame aerial can be extremely effective for reducing interference, however if the source of the interference is from within the house then it made carried and radiated by internal wiring and could come from all sorts of different directions and the directional properties of a loop may not be so useful. It is still worth a try though, so see our loop/frame aerial page HERE.

Query Two (A similar question):

Hi there

I found your interesting site whilst browsing the web looking for information on getting better quality MW and LW radio reception whilst travelling around W and C France. I spend quite a lot of time near Bordeaux and would really like to be able to pick up british stations on these frequencies. My existing portable radio is now pretty dead after many years of use. I was wondering if you had any suggestions on which models could make a good

replacement?

Many thanks, Jon

Reply

Hi Jon,

Long distance stations will certainly come in better at dusk, night and early morning. I listened to Capital Radio from London many many years ago in central France at these times.

I cannot guarantee that you would get medium wave stations from the UK during the day, but the use of a loop aerial may be well worth a try. I would certainly expect to be able to get Radio Four on Long Wave during the day using a loop aerial in central France.

My general advice would be to use a good quality receiver from a well known manufacturer, i.e. Sony, Panasonic, Sangean / Roberts (Roberts re-badge Sangean radios and tend to be more expensive than the Sangean equivalent.) and just as importantly, is to use an effective aerial. I would recommend a loop aerial of approximately 14 inches in diameter for travel use.

Rather than buy a new radio first off, I would make the loop aerial. However you cannot buy them, but if you are quite good at using a screw driver, pliers and saw etc and think that you could turn your hand to some easy soldering (i.e. a bit of very simple DIY) then it should not be very difficult to make a loop aerial - well two aerials actually would be more effective - one that will tune across the medium wave band and another that could be fixed to 198 kHz long wave for BBC Radio Four.

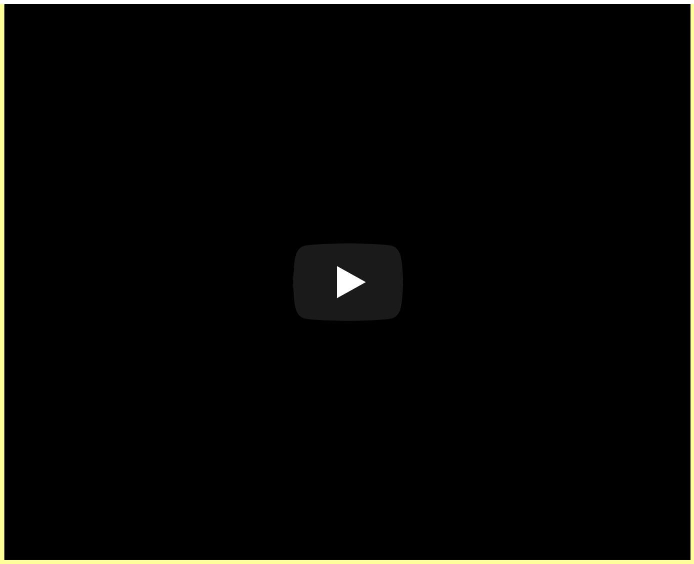
Short Wave Radio - Amateur Radio and Citizens Band Radio Under Threat

From "HomePlug Networking" Broadband by Powerline Devices

SHORT WAVE (H.F.) RADIO, INCLUDING AMATEUR RADIO, IS THREATENED WITH MASSIVE AMOUNTS OF INTERFERENCE CAUSED BY British Telecom's BT HomeHub / Vision PowerLineAdapters & OTHER SIMILARLY UNNECESSARY 'B.P.L' & 'PLT' PRODUCTS.

Radio interference from BT Home Hub / Vision PowerLine Adapters and other similar devices could also threaten YOUR broadcast radio reception with vast amounts of radio interference.

More Information >>



FOOTNOTE: SOME INTERESTING OLD FREQUENCIES

Below are some frequencies identified in an old Lowe Listeners Guide. Some of them can still reveal very interesing results particularly in Marine or Air communications. Most of these frequencies lie outside the general Broadcast Bands so many will use the Sideband mode of transmission. Usually Lower Lideband (LSB) for frequencies below 10MHz and Upper Sideband (USB) for frequencies above 10MHz.

If you want to listen to general broadcast programmes then consult THE BANDS table above, but before you go there just have a tune around in the space between those broadcast bands - it can be fascinating, but don't expect to hear something immediately and do remember that this is now a very old list.......

3366KHz
Ghana Broadcasting. This is an excellent test station to see if this classic DX band is open. Try around midnight. As we slowly creep up the HF spectrum, signals penetrate the E Layer only to be reflected down again by the F Layer. As this layer is twice the height of the E Layer, the reflected signal comes to your antenna from a much greater distance. This effect is what gives 80m its European coverage by night. By day it remains The Great UK Natter-band.

3650KHz
Allocated frequency for GB2RS RSGB UK News. Costing over £5000 a year to run, the future of the RSGB News is under constant review. For the writer, the first sideband station he resolved, for the new generation of radio ham something of an anachronism. Stalwarts only need listen for useful reports of solar activity - if you can understand them - details of Club Events and radio rallies in the summer. The writer has been out of Ham Radio for years but still finds himself listening on Sundays at 0930z. We miss you, Fred G2CVV..

The 4Mhz Land/Marine Mobile Band

4125KHz: Marine Distress International.

4138KHz: Arctic Seas Distress

4138KHz: Arctic Seas Distress.

4220KHz: Arctic Seas Supplementary.

4594KHz Numbers station.

The return of the number stations may have a lot to do with conditions, but the routines suggest mere testing of old equipment, a lot of transmissions being in AM.

4742KHz RAF Flight Watch: "Architect listening out."

Architect is the Flight Watch callsign. Despite all the new technology, the main enemy to operations is the weather. This code is given at fixed times and upon request to pilots preparing to fly between British airbases. From this we will learn that a Wattisham Blue has little to do with being an all-round good egg while up at University, but "Forever Amber" is a good status for most of my holidays in Wales. Other flight watch frequencies are included in the lists. Serious HF airband operation will need one of the better receivers with a stable sideband operation and a large number of memories to allow rapid channel hopping.

4750KHz
The lower limit of the 60m Tropical Band. Allocated only in the tropics, this band gives up some musical treats in the late evenings. And it's getting better;

4770KHz
Radio Nigeria. Long today's dance trends set the nations feet to dance to the urgent guitars of World Music via BBC Radio 1, those of us blessed with short-wave could hear the opium of the people on The Tropical Band without the need for mosquito nets and funny injections...

4882KHz
Letter Station. Just as the reviewer sharpens his pencil to have a go at the endless entries for so-called "number stations", the ionosphere rings the changes with a station sending five letter groups.

This one sends IOBMJ, "India/Oscar/Bravo/Mike/Juliet" ad nauseam.

5080KHz
East Coast Control.

5095KHz
Buchan Control. Examples of Air Defence Radar Units.

6211KHz: Northern Seas Supplementary Distress.

6215KHz: Marine Distress.

6224KHz: Thames Control.

Many Sunday Pirates have moved to the 75 Metre band.

6300KHz
Russian number station. "Golly, Control, you don't think they are at it again?"

No, we don't. The modulation quality suggests some very old plant is just being given an airing. They tell us the price of freedom is eternal vigilance, so you never can tell...

6622KHz
Shannon ATC. Secondary calling on 8831.

7265KHz
Sudwestfunk, Baden-Baden, Germany. Real radio as a public utility. Nothing but a rich mix of pop and rock from albums, news, weather and travel information. Listen for the pulse of RDS data that switches over a million German radios to this network for the latest update.

7860.5KHz Army Signals. "That man there! Absolute shower!"

The 8Mhz Mobile Band

Including:

8228KHz: Ostende Radio.

8291KHz: Marine Distress.

8634KHz: Ships Survival Craft.

8737KHz: Cyprus Maritime Radio Service.

8825KHz: North Atlantic Control.

8846KHz: New York Radio. Secondary calling on 6577.

8864KHz: Shannon ATC.

8879KHz: Shannon ATC.

8891KHz: Shannon ATC.

8957KHz: Shannon Volmet.

9031KHz: RAF Flight Watch and Gibraltar Forward Relay.

9251KHz: "The Lincolnshire Poacher". Classic English number station.

9830KHz: Croatian Radio. News heard at 0800.

10000.0KHz
Calibration Beacon. Many countries compete to provide a Reference Standard, so much so that 10000 is merely the middle of a standard's sub-band. The one you find could be up to 5KHz away from what you take to be 10000 leaving you to question the accuracy of your radio. Chances are that if it was made in the last decade of synthesizer design, then all will be well. Standards can confuse as well as assist...

An example: Callsign RWM from Moscow is the strongest SFS station in Europe and can be heard on 4996, 9996 or 14996kHz throughout the 24 hours. It sends five minutes of unmodulated carrier, five minutes of one second pulses and five minutes of one tenth second pulses. The latter have to be unfiltered with a sharp leading edge for precision purposes, which results in key click splatter being heard around the world. For frequency calibration and propagation checking purposes these SFS stations are ideal, but don't forget that radio signals take around one seventh of a second to travel around the world. The timing is, however, sufficiently precise for meteor scatter schedules.

10051KHz: New York Radio.

111660KHz: Radio Australia (recprion from about 3pm in England - added 2005 by Roger Sharp).

12290KHz: Marine Distress.

12392KHz: Marine World-wide Calling and Distress.

The 13Mhz Long Distance Mobile Band

The major world-wide mobile communications band;

13146KHz: Portishead Radio. Traffic and Weather on the hour.

13270KHz: New York/Gander Radio.

16420KHz: Marine Distress.

18930KHz: WEWN.

Happy listening and good DX,
Mike

^Top Of Page

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My Amateur Radio Call Sign is MØMTJ

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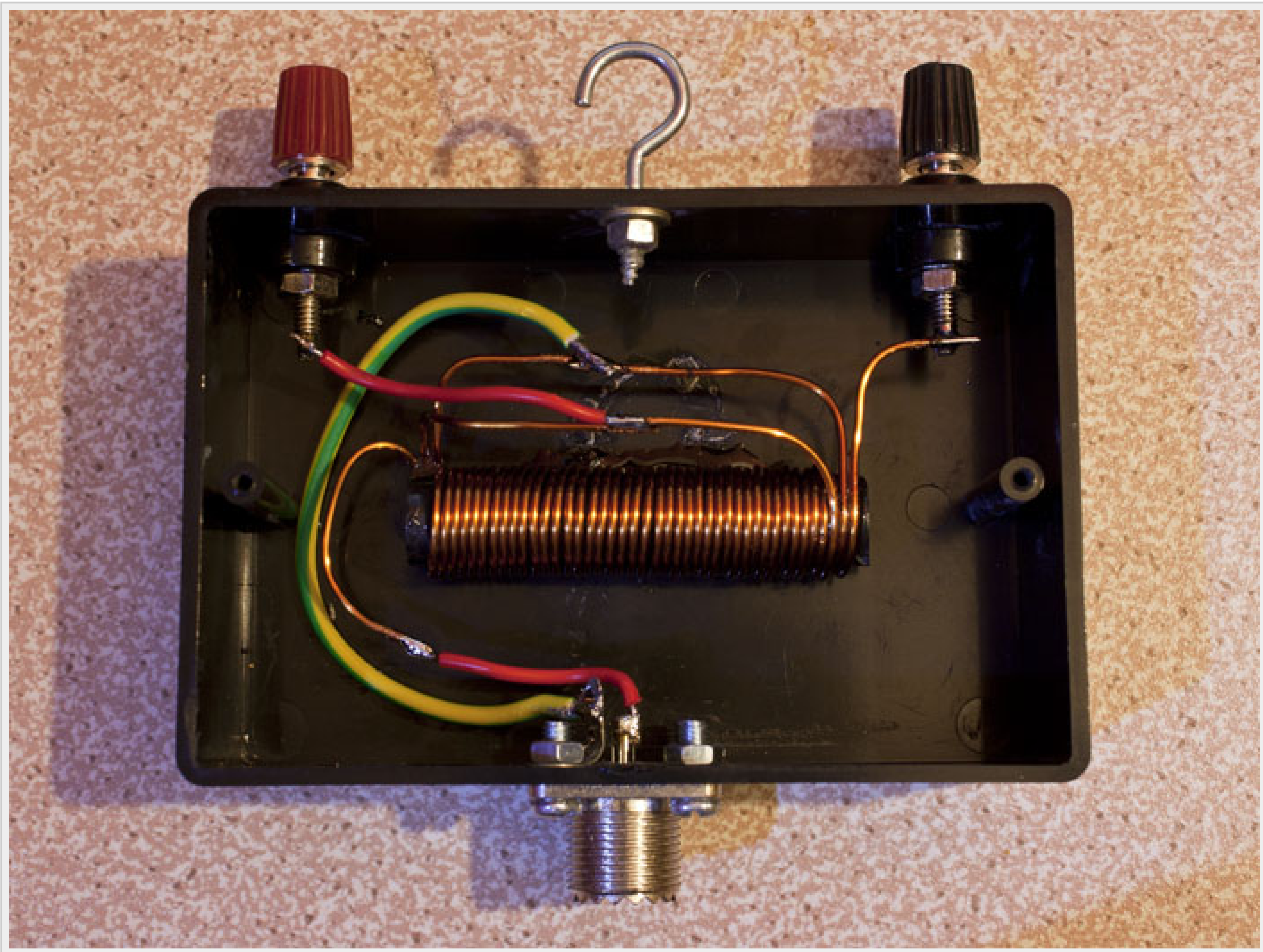
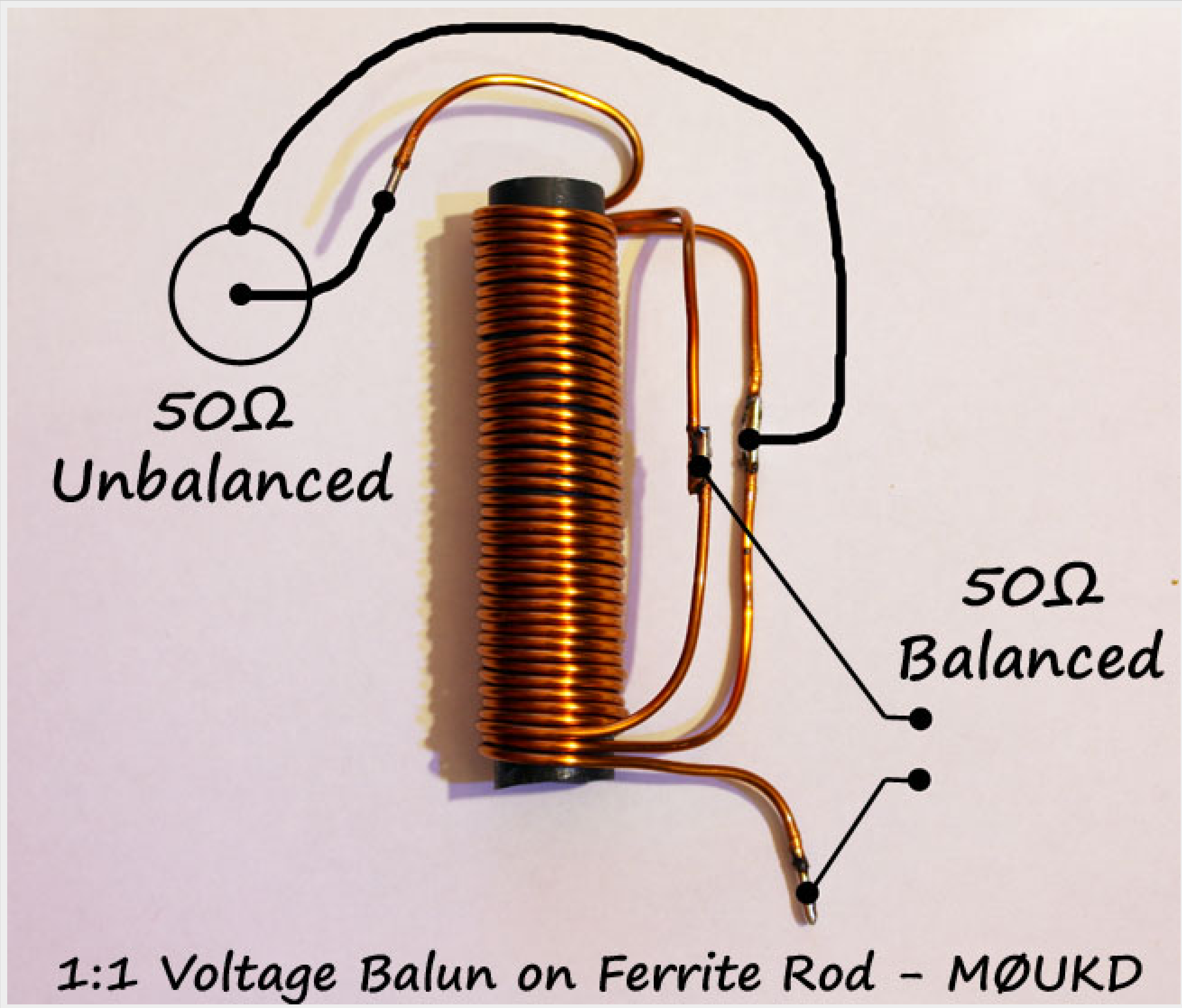
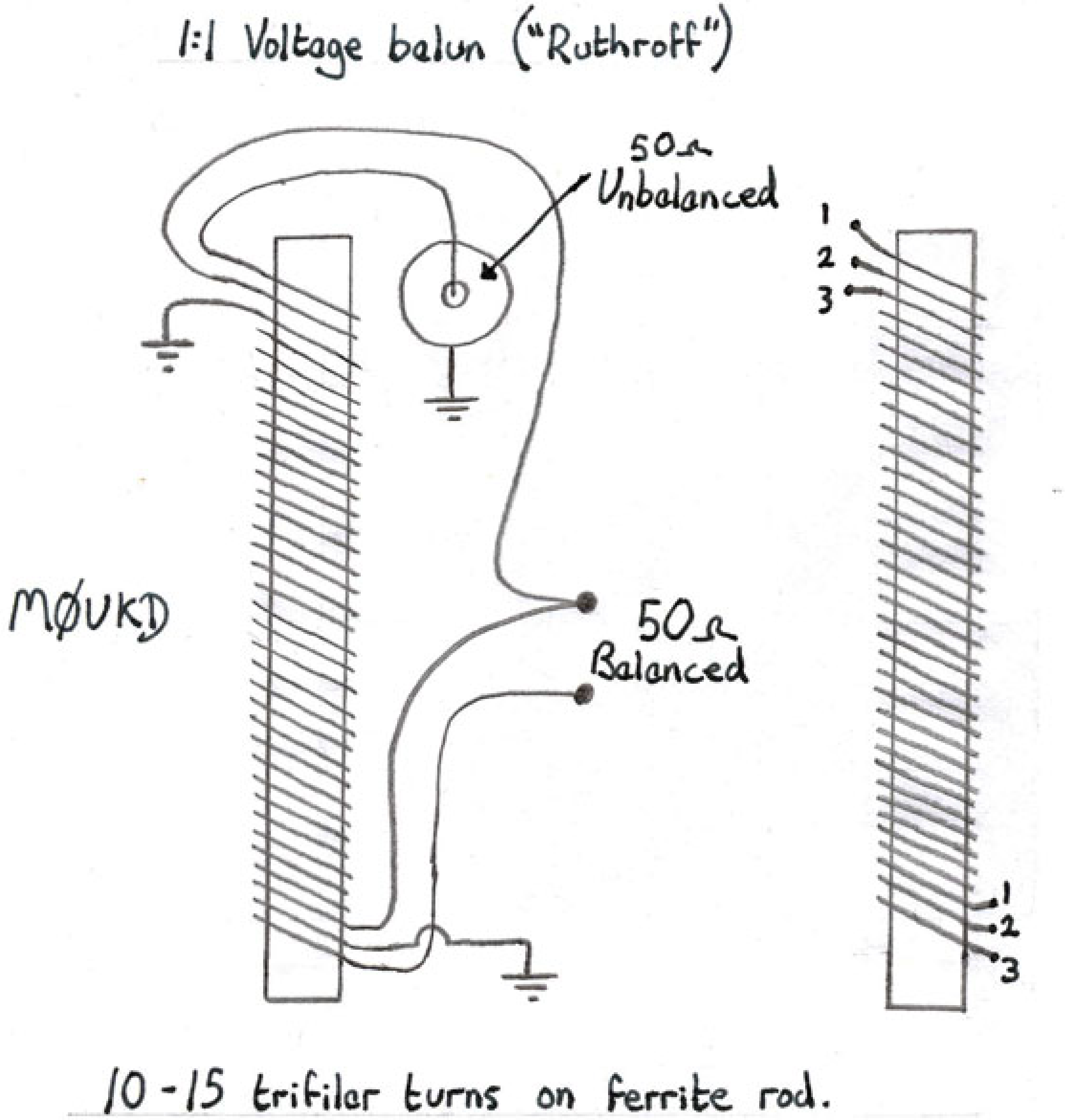
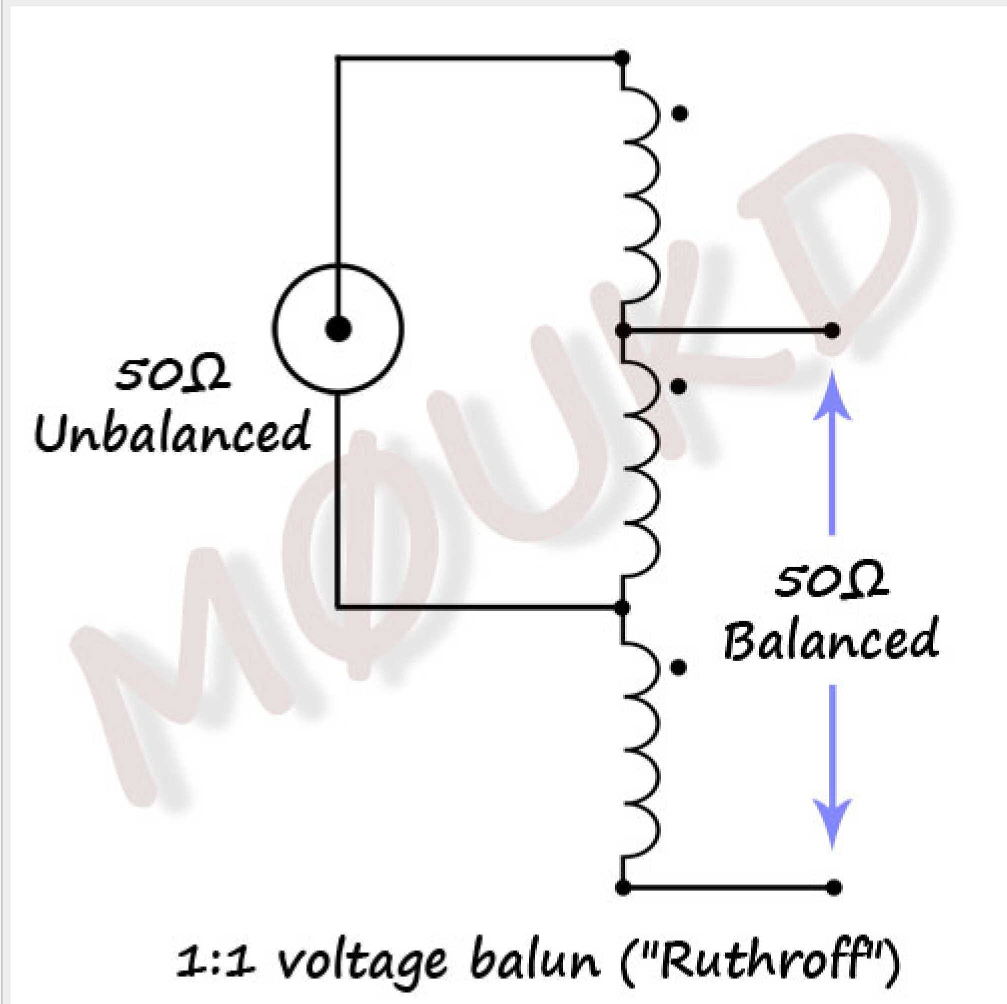
1:1 Voltage Balun for HF wire dipoles




50Ω
Unbalanced
50Ω
Balanced
1:1 Voltage Balun on Ferrite Rod - MØUKD


1:1 Voltage balun ("Ruthroff")
50Ω
Unbalanced
1
2
3
MØUKD
50Ω
Balanced
1
2
3
10 - 15 trifiler turns on ferrite rod.


50Ω
Unbalanced
50Ω
Balanced
MØUKD
1:1 voltage balun ("Ruthroff")

Accept

A Dual-Band Slot-Embedded Microstrip Antenna for Dual-Polarization Operation

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A Dual-Band Slot-Embedded Microstrip Antenna for Dual-Polarization Operation

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Abstract—In this study, a new slot embedded microstrip antenna for dual-band dual-polarization operation is proposed. The antenna comprises a single layer structure with a square radiating patch where the feed port is located along a diagonal line of the patch. Two narrow slots parallel and close to the radiating edges of the patch are loaded on the patch. Patch without slots is resonated for X-band and another resonant frequency at Ku-band is obtained by loading the slots. Moreover, the loading of slots helps to produce two orthogonal modes of equal amplitudes at X-band. Furthermore, the feed port along the diagonal line of the square patch makes it possible to radiate different polarization at the two bands. The antenna can radiate circular and linear polarization at X- and Ku-band, respectively. Current distributions of the antenna at both bands are observed to explain the behavior of the antenna and confirm the polarization characteristics at X- and Ku-band. A 3-dB axial ratio bandwidth of 1.35% is achieved. Measured gains of 6.60 dBic and 5.80 dBi with good radiation performances are achieved at X- and Ku-band, respectively. Moreover, good measured cross-polarization levels of 27.6 dB at X-band and 15.6 dB at Ku-band are obtained. The measured performances of the fabricated antenna are consistent with simulated results.

1. INTRODUCTION

Due to the rapid progress of wireless and satellite communication systems, multi-band antennas are very attractive for various communication applications. Furthermore, multi-band microstrip antennas with polarization diversity capability offer the advantages of low profile, low cost, and multi-use capability in different applications. Different techniques and geometries of multi-band antennas have been proposed in the last several years to produce either the same polarization or different polarizations in the frequency bands. One of the main techniques to design dual-band antennas is by inserting slots on the patch; for example, two narrow and parallel slots can be inserted near to the radiating edges of a rectangular patch [1, 2]. A bow-tie microstrip antenna for dual-band operation has been demonstrated in [3]. A pair of narrow slots is embedded close to the radiating edges to achieve dual-frequency operation. Moreover, a pair of step-slots [4] or a pair of properly-bent narrow slots [5] embedded near the non-radiating edges of a rectangular microstrip patch have also been reported. Another dual-band antenna applying two arc-shaped slots integrated close to the edge of the circular microstrip patch has been studied in [6]. These antennas exhibit linear polarization (LP) at both bands. In [7, 8], dual-band circular polarization (CP) antennas have been demonstrated. A slot-loaded square patch with two feeding points has been used in [7], wherein four equal shaped slots are loaded close to the edges of the patch. A small circular patch surrounded by two concentric annular-rings that are loaded by an unequal lateral cross-slot ground plane has been presented for dual-band CP operation [8]. A CP antenna using metamaterial for WiMAX applications has been presented in [9], wherein two split ring resonators (SRR) are implemented

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to realize CP. The SRR structure changes the current path on the antenna to create a loop. Therefore, this structure works in a single band with CP radiation. However, the slot-loaded antennas mentioned in [1–8] act as dual-band antennas because the loaded pair of slots introduces another higher order resonant frequency and modifies the current distribution on the band to obtain a radiation pattern similar to the lower resonant frequency [1]. In [10], an aperture coupled square microstrip patch with a dual-band polarization reconfigurable capability has been described for wireless local area network (WLAN) systems. The frequency ratio of this antenna is adjusted by inserting four shorting posts into the patch and polarization switching among horizontal, vertical, and 45° LP is realized by changing the states of the PIN diodes connected between the center of each edge of the patch and ground. Another dual-band dual-polarization capacitive-fed circular patch antenna operated at 1.575 and 2.4 GHz has been presented in [11], wherein a 90° hybrid coupler chip is used to produce CP at 1.575 GHz and a pair of arc-shaped slots is embedded in the patch to radiate LP at 2.4 GHz. A dual-layer dual-band dual-LP reflectarray antenna using a cross dipole, modified phoenix loop, and square patch has been demonstrated in [12] for Ka- and W-band operation. A planar triple-strip monopole antenna [13] and a CPW-fed inverted-annular shaped antenna [14] have been presented for dual-band dual circular polarization operation.

In this study, a new dual-band dual-polarization microstrip patch antenna for X- and Ku-band applications is proposed. Moreover, this dual-band antenna can be modified to be assigned to global positioning system (GPS) and Wi-Fi applications because CP is vital for GPS antenna to obtain optimal performance, and an LP antenna is enough to support the Wi-Fi communication. Following the basic concept of [1, 2], two narrow and parallel slots are loaded on an X-band patch so that the proposed antenna can simultaneously operate at X- and Ku-band. CP at X-band and LP at Ku-band are achieved by placing the feed port along a diagonal line of the patch. The performances of the antenna are experimentally confirmed, and the design of the antenna along with measured and simulated results is discussed in the subsequent sections.

2. ANTENNA CONFIGURATION

Figure 1 illustrates the design of the proposed antenna. The square patch of length L is designed on a Teflon substrate whose permittivity and thickness are ε_r and h, respectively. Two narrow and parallel slots with equal length S_l and width S_w are incorporated near the radiating edges of the patch. The horizontal and vertical distances of the each slot from the edges of the patch are w and g, respectively.

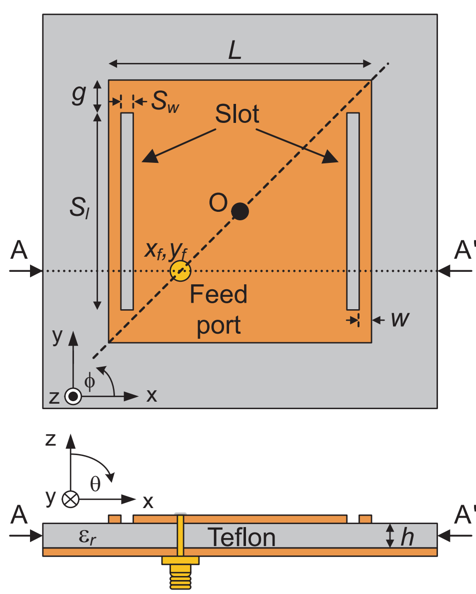


Figure 1. Schematic layout and cross-sectional (A-A′) view of the proposed antenna.

The feed port is placed along a diagonal line of the patch and the feed port position is $(x_f,\, y_f)$ with respect to the center point O of the patch.

The concept of the proposed antenna has been adapted from the antenna presented in [1, 2]. By comparing both structures, it is noticed that the patch geometry and the feed location of the proposed antenna are altered to obtain dual-band dual-polarization characteristics. A square patch is used in the proposed antenna instead of a rectangular patch used in [1, 2]. Moreover, the feed position is set along a diagonal line of the patch, whereas the feed port in the previous work was along the center line of the patch.

Figures 2 and 3 show the effect of changing slot length S_l on the S_{11} and axial ratio (AR) of the proposed antenna. The unslotted patch is designed for X-band. The size of the slots needs to be adjusted to obtain optimum performance at both frequency bands. In X-band, the slots help to radiate CP, but they do not have any effect on the designed frequency of the patch because the narrow slots loaded near to the radiating patch edges are at a position where the patch current is a minimum. The size of the two parallel slots should be attuned properly to produce two orthogonal modes so that the sense of polarization can be CP, as shown in Fig. 3. In addition, Fig. 2 shows that the loading of the slots on the patch has a very small impact on the resonant frequency at X-band. In contrast, the

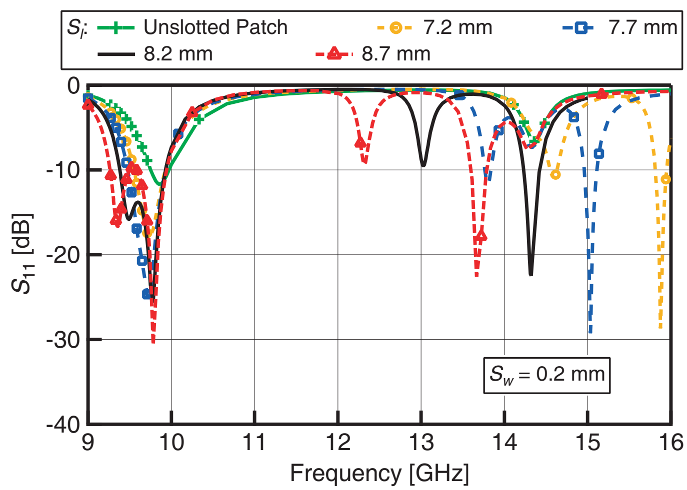


Figure 2. Effect of the slot length S_l on the S_{11} of the antenna.

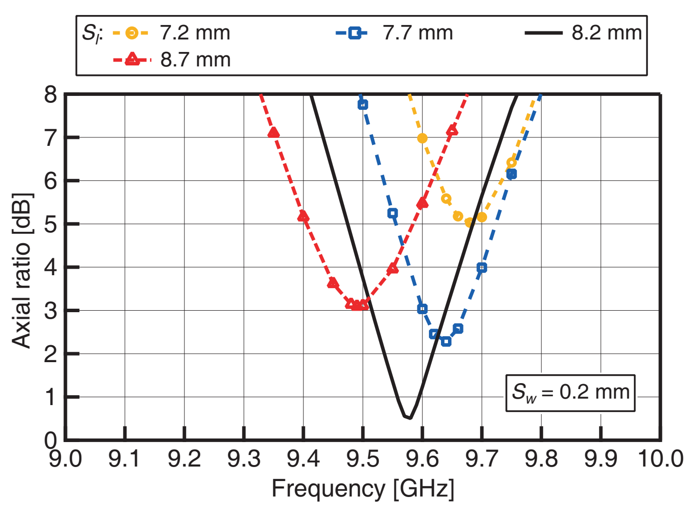


Figure 3. Effect of the slot length S_l on the axial ratio of the antenna.

loading of slots introduces another resonant frequency at Ku-band where the polarization sense is LP. The length of the slots S_l has an impact in introducing this resonant frequency. In addition, a higher order undesired mode causes another resonant frequency at the Ku-band.

Figures 4 and 5 illustrate the effect of the variation of slot width S_w on the S_{11} and AR of the antenna. According to the figures, the slot width S_w has no effect on the resonant frequency at two bands. Though the slot width S_w does not affect the resonant frequencies, the slot width S_w should be adjusted to obtain minimum AR at X-band. Therefore, an optimum slot size must be determined to achieve the optimal performances from the antenna at both bands.

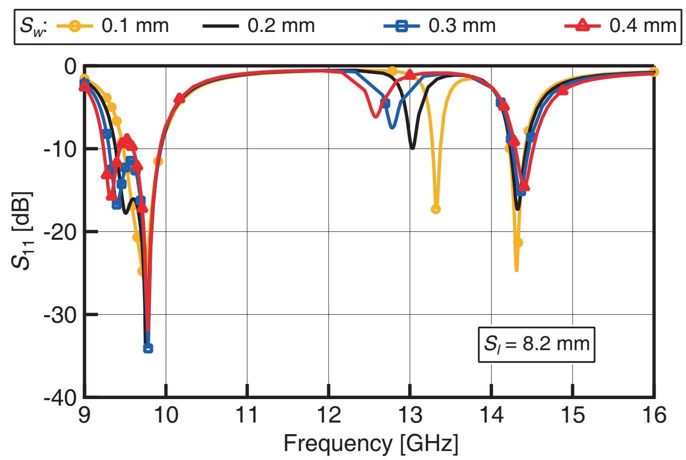


Figure 4. Effect of the slot width S_w on the S_{11} of the antenna.

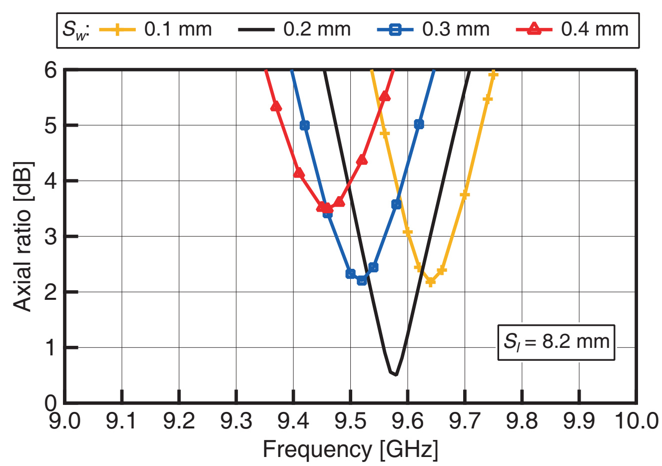


Figure 5. Effect of the slot width S_w on the axial ratio of the antenna.

Figure 6 shows the simulated current distribution of the proposed antenna for different polarizations at different phases. For the surface current shown in Fig. 6(a), the embedded slots do not affect the current at 9.56 GHz, and the field rotation is in a clockwise direction. Consequently, the polarization sense in this band is left-handed CP (LHCP). In contrast, at 14.46 GHz, the maximum current is accumulated around the slots. Therefore, these slots introduce another resonant frequency in this band. As the slots provide a shorter horizontal electrical current path than that of the vertical path, LP is radiated.

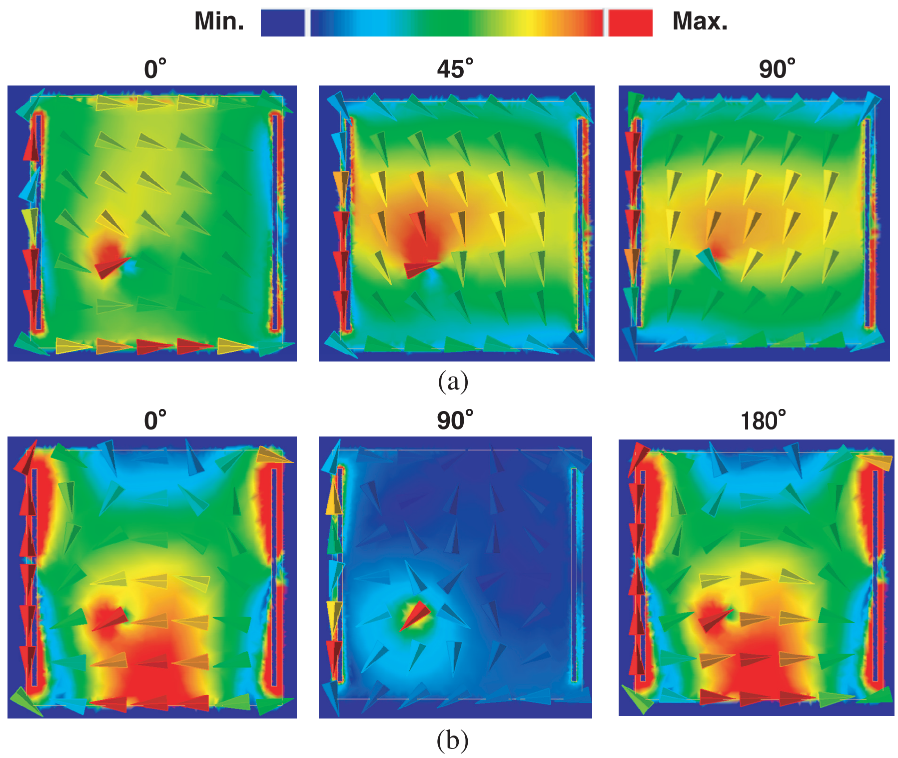
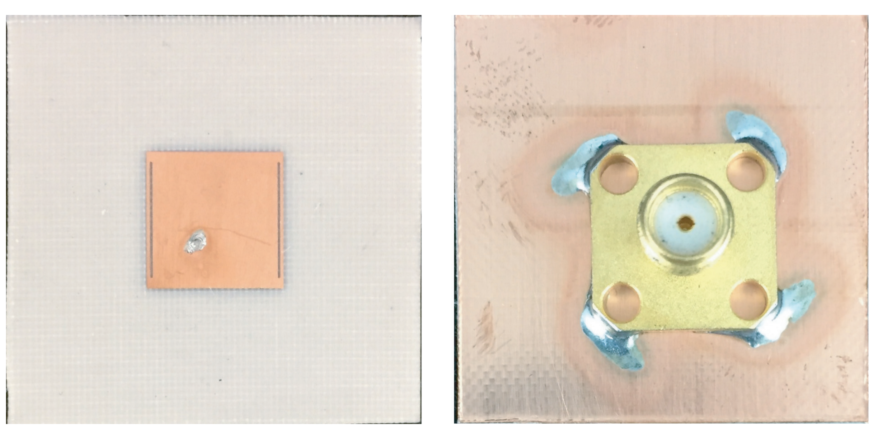


Figure 6. Current distribution of the proposed antenna at different phases. (a) $f = 9.56\,\text{GHz}$ (CP). (b) $f = 14.46\,\text{GHz}$ (LP).

3. ANTENNA PERFORMANCES

Figure 7 shows the top and bottom views of the fabricated antenna. The antenna is etched on a 0.8-mm thick Teflon substrate with a permittivity of 2.15. The dimension of the ground plane of the antenna is $28.8\,\text{mm} \times 28.8\,\text{mm}$. The various dimensions of the fabricated antenna are as follows: $L = 9.6\,\text{mm}$, $S_l = 8.2\,\text{mm}$, $S_w = 0.2\,\text{mm}$, $g = 0.7\,\text{mm}$, $w = 0.2\,\text{mm}$, and $x_f = y_f = 1.5\,\text{mm}$. Initially the antenna has been designed and simulated using Momentum of Keysight Technologies' Advanced Design System (ADS) and after that the performances has been validated using FEM of EMPro. The performances of the fabricated antenna have been investigated by using a HP8510C network analyzer.



(a) (b)

Figure 7. Photograph of the fabricated antenna ($28.8\,\text{mm} \times 28.8\,\text{mm}$). (a) Top view. (b) Bottom view.

Figure 8 presents the measured and simulated reflection coefficients of the antenna. The measured 10-dB impedance bandwidths of the antenna at X- and Ku-band are 5.17% and 1.15%, respectively. The measured and simulated results show almost similar reflection coefficients with a slight frequency shift in the measured result at Ku-band. As shown in Fig. 2, the slot length affects the resonant frequency. Therefore, this frequency shift is caused by the slot length imperfection that occured during fabrication. Moreover, simulation imperfection can be another reason for this mismatch because a frequency shift is also observed in the comparison between ADS and EMPro simulation results.

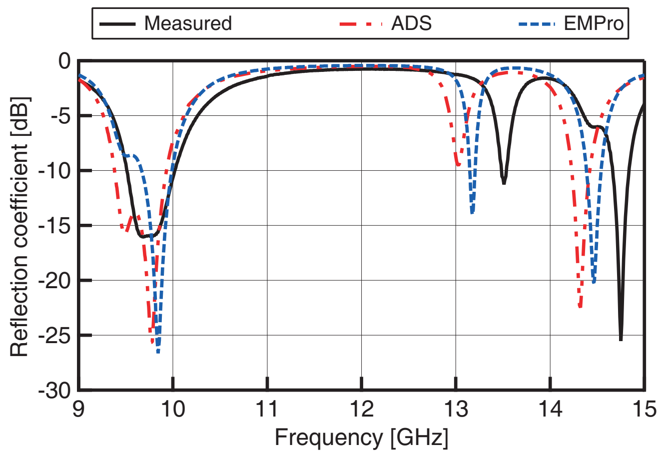


Figure 8. Reflection coefficient of the antenna.

Figure 9 shows the measured AR of the antenna with simulated results. A measured 3-dB AR bandwidth of 1.35% is obtained with a minimum value of 0.23 dB at 9.64 GHz. The measured and simulated AR performances are well matched.

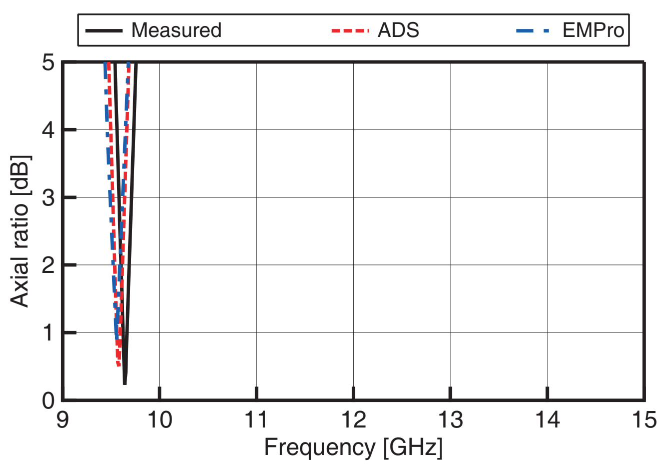


Figure 9. Axial ratio of the proposed antenna.

Figure 10 shows the measured and simulated radiation performances of the antenna at 9.64 GHz for both x-z and y-z planes. The measured and simulated gains of the antenna are around 6.60 dBic and 8 dBic, respectively. At both planes, the gains of the antenna are almost same.

Figure 11 illustrates the CP radiation performance of the antenna at 9.64 GHz for the x-z plane. The proposed antenna radiates LHCP, and the measured cross-polarization CP component is below -27.6 dB that indicates good CP performance of the antenna at X-band. As the simulated AR is minimum at 9.56 GHz, the measured and simulated CP radiation performances are plotted in this graph at each frequency of its minimum AR value for good understanding.

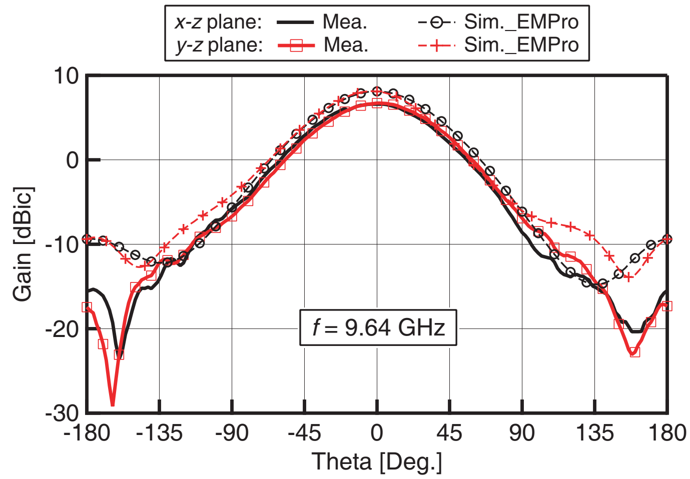


Figure 10. Gain of the antenna at X-band.

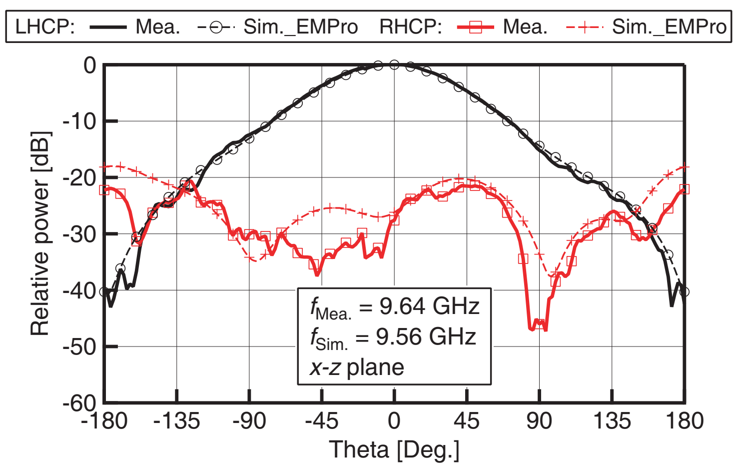


Figure 11. CP radiation performance at X-band. The measured and simulated results are plotted for the frequencies where the AR is minimum.

Figures 12 and 13 present the radiation performance of the antenna at Ku-band for x-z and y-z planes, respectively. In this frequency band, the antenna radiates LP. The measured gain of the antenna at Ku-band is about 5.80 dBi for both planes, whereas simulated gain is around 3.90 dBi. Although a good impedance matching is obtained at 14.75 GHz, the simulated S_{11} is above -10 dB at the same frequency as shown in Fig. 8. This might be the main reason for the discrepancy between the measured and simulated gains. The cross-polarization level is better than 13.7 and 15.6 dB at the x-z and y-z planes, respectively.

Table 1 presents a comparison between the proposed antenna and previously reported slot-embedded dual-band antennas. Most of the antennas related to slot-loaded dual-band antennas without using any active and/or passive devices radiate the same polarization in the both bands. The antennas compared with this work in Table 1 are linearly polarized in both bands. Besides, the antenna reported in [7] radiates CP in the two bands by embedding four slots and two feed ports. There is no slot-loaded antenna without integrating active and/or passive devices where the two resonant frequencies have different polarizations. In contrast, the antenna proposed in this study shows distinct polarization in the two different bands.

Finally, the proposed dual-band antenna is compared with a conventional X-band CP antenna and a Ku-band LP antenna. For proper comparison, a Ku-band LP square patch antenna with a center frequency of 14.75 GHz is designed. Besides, an X-band perturbed type CP antenna is designed to have

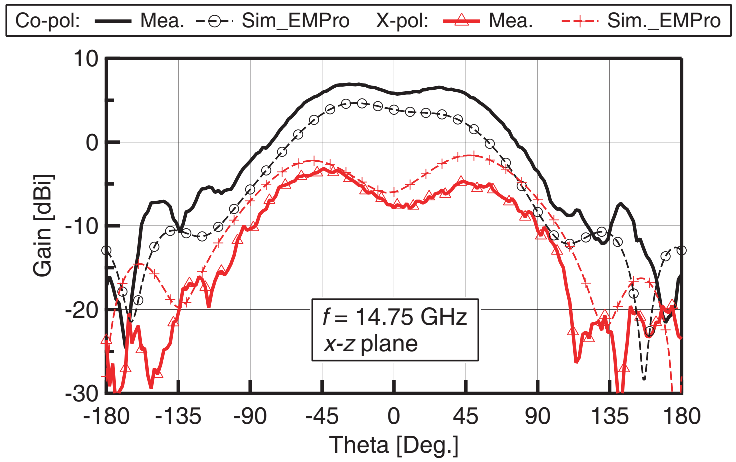


Figure 12. Gain of the antenna at Ku-band for x-z plane.

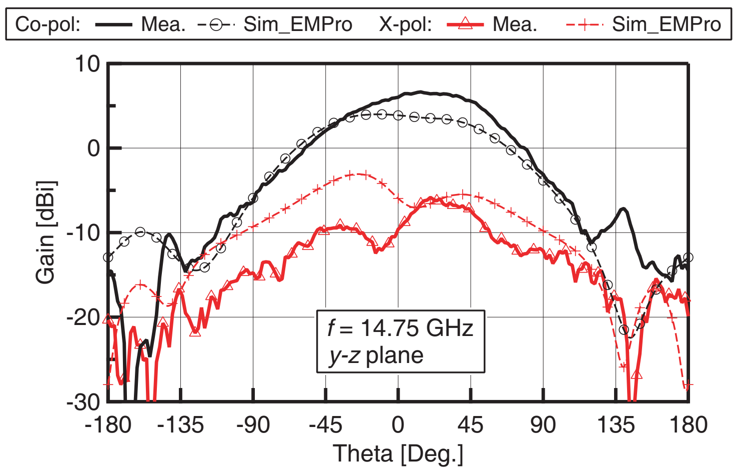


Figure 13. Gain of the antenna at Ku-band for y-z plane.

Table 1. Comparison of the proposed antenna with the previously reported slot-loaded antennas.

Antennas	Bands	Technique	CP/LP	Impedance BW (< -10 dB)	AR BW (< 3 dB)
[1]	C, X	Pair of line slots	LP	0.80%, 1.20%	-
[3]	L, S	Slot-loaded bow-tie antenna	LP	1.32%, 1.15%	-
[4]	L, S	Pair of step slots	LP	1.76%, 1.42%	-
[5]	L, S	Pair of bent slots	LP	1.56%, 1.38%	-
[6]	L, S	Pair of arc-shaped slots	LP	1.60%, 1.38%	-
[7]	S	Four slots & two feed ports	CP	-	-
This work	X, Ku	Pair of line slots	CP/LP	5.17%, 1.15%	1.35%

a minimum AR at 9.63 GHz. The impedance bandwidths of the X-band CP antenna and Ku-band LP antenna are 5.5% and 4.75% whereas a 3-dB AR bandwidth of 1.45% is achieved at X-band. The gains of these antennas are around 7.06 dBic at 9.63 GHz and 7 dBi at 14.75 GHz. The proposed antenna has similar performances at X-band to the conventional X-band CP antenna. However, the antenna performances are worse than the conventional Ku-band LP antenna because the proposed antenna is

originally an X-band antenna that is optimized to radiate at Ku-band by loading a pair of slots. Thus, these slots change the current distribution that is not similar to that of conventional Ku-band LP antenna. Therefore, the performances of the proposed antenna at Ku-band are deteriorated than a conventional antenna.

4. CONCLUSION

A square microstrip patch antenna geometry comprising two parallel and narrow slots close to the radiating edges on the patch has been demonstrated to produce dual-polarization at two different frequency bands. Two different polarizations are achieved by placing the feed position along the diagonal line of the patch. CP and LP radiation can be obtained using this antenna at X- and Ku-bands, respectively. The performances of the antenna are verified and demonstrated using measurement, and good performances are found at both frequency bands.

ACKNOWLEDGMENT

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DIY Audio Home

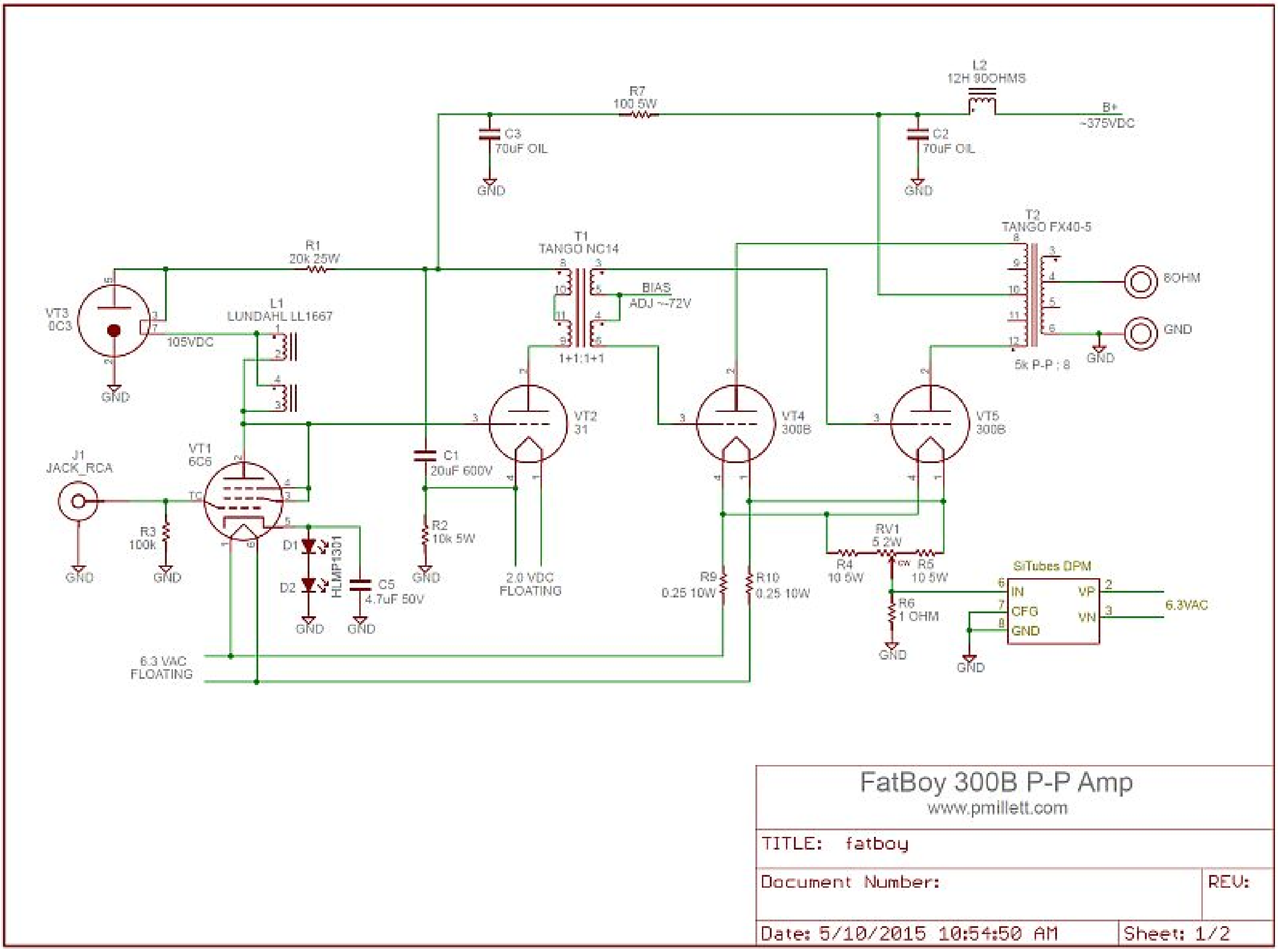
"Fatboy" 300B push-pull amp

The last few amplifiers that I've designed used pentodes and lots of NFB to get low distortion.

So I decided to go to the other extreme: how low distortion could I achieve with no negative feedback of any kind. The result is the "Fatboy" 300B amp - named as such because, like me, it is a tad overweight.

Amp Design

The circuit design is old school: Choke-loaded triode direct coupled to DHT driver, transformer coupled to the push-pull 300B output tubes. I used Tango NC-14 interstage and FX40-5 output transformers, which I've had around for a while. Since there is no NFB I'm sure you can use other iron that is more available now. You might need to tweak the driver circuit to optimize it for a different IT, though.



Download a PDF version of the schematic

The choice of input and driver tubes was made experimentally. No distortion cancellation going on here (other than the P-P 300B pair) - I tweaked each stage individually for the lowest possible distortion. That's how I wound up with some uncommon tube choices.

The 6C6 is essentially a 6-pin version of the 6J7, which is the top cap version of the 6SJ7. OK, purists, you can claim that using a pentode in triode connection is actually a form of feedback. My argument is that it's just a different way of building a triode! In any case, the 6C6 measured better than the 6J7 and 6SJ7. I don't know why. BTW, a 6SN7 measured well here too, but didn't have enough gain. I tried some more modern tubes like the 7044 and 5687, but this was the best. The 6C6 is biased with a pair of LEDs. Note the parallel cap - yes, it did make a difference - about 1dB at high frequency.

I'm always cautious about direct coupling, because bias shifts in the first stage can cause big shifts in the second. I avoided that issue here by using choke loading driven from a VR-tube-regulated supply. In this way, the grid of the driver tube pretty much always sits very close to the VR tube voltage, so the bias on the driver (provided by a big cathode resistor) doesn't move much.

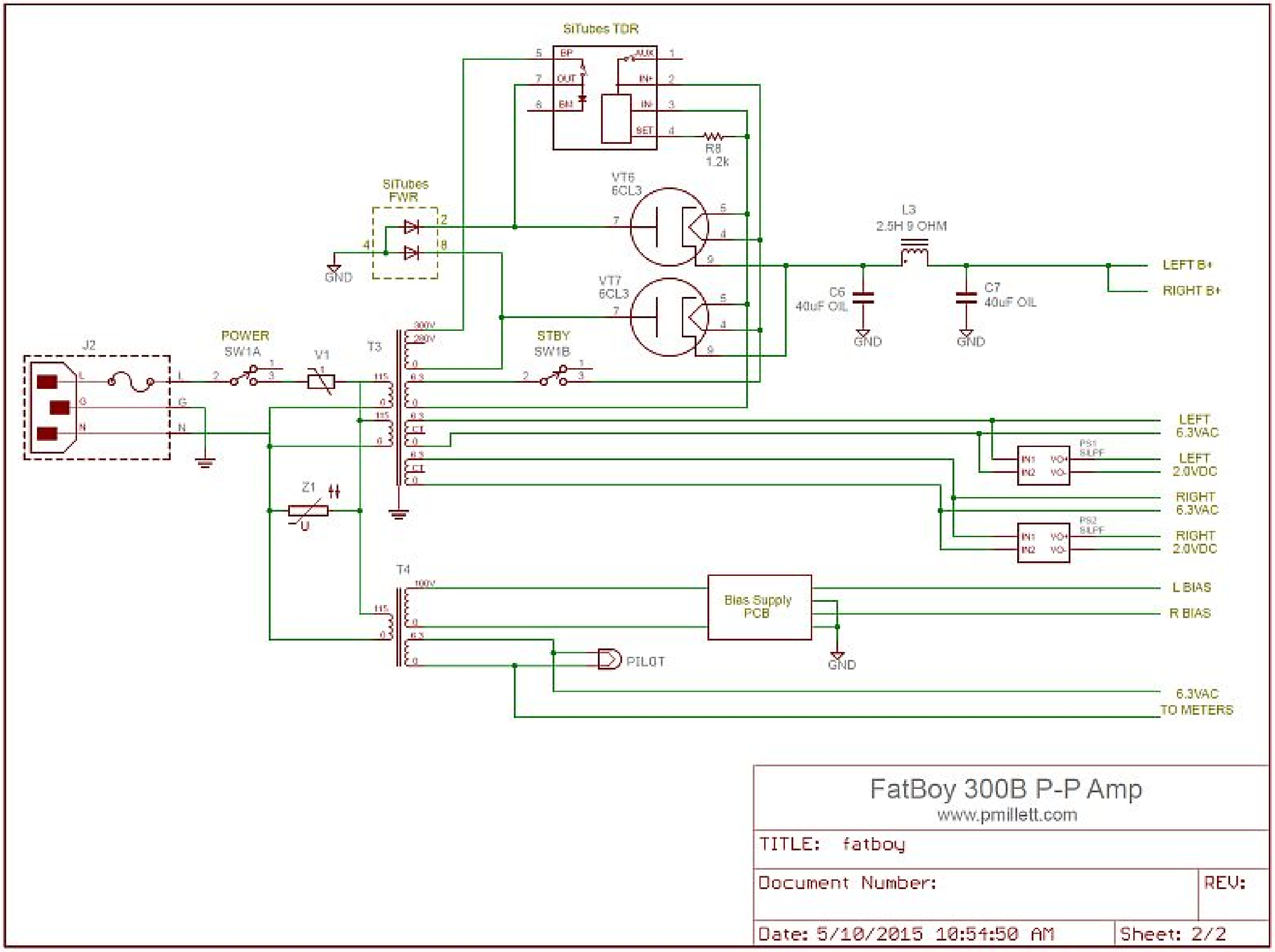
The 31 driver is a fairly cheap and unpopular DHT. Designed as an output tube for battery radios that put out a couple hundred mW of audio, its low Rp makes a really good interstage transformer driver. I tried a number of different tubes (including the ones recommended on the Tango datasheet) to drive the NC-14, and this was the best I had.

The output stage is a matched pair of 300B tubes. Filaments are heated by AC, with a couple of dropping resistors from the main 6.3V heater circuit. A standard hum balance pot arrangement is used, and a 1 ohm resistor to sense cathode current. That connects to a digital panel meter (SiTubes DPM, a meter-in-a-tube-bottle). There is still a few mV of 60Hz present on the output, but it was not noticeable even with my ear in front of Klipsch Heresy speakers.

So, how did it work? About 0.08% THD at 1W, and only about 0.2% at 10W (1kHz into 8 ohms). But more measurements later...

Power Supply

As is often the case, the power supply is more complicated than the amplifier itself.



The power supply generates a B+ voltage of around 375V, at 350-400mA for the stereo amp. B+ is generated from a 300V RMS winding on a monster James power transformer that I found in Taiwan. A hybrid bridge is used, using a pair of 6CL3 tubes on the positive side, and SiC Schottky rectifiers on the negative side. A B+ delay relay is inserted in series with one side of the transformer winding to make sure that under all conditions the filaments have time to heat before B+ is applied. The B+ delay relay and the SiC diodes are contained inside octal tube envelopes to make point-to-point wiring easier. For details on these modules, see www.situbes.com.

The filter choke arrangement uses a 40uF oil cap into a large 2.5H, 9 ohm James choke, and another 40uF oil cap. Then, each channel gets another 12H choke and 70uF oil cap (these are shown on the schematic above). The driver is decoupled with 100 ohms and another 70uF oil cap.

Grid bias for the 300B tubes is generated by a shunt-regulated bias supply PCB that I designed. It outputs nominally -72V for each pair of tubes. I didn't include any individual tube bias or balance adjustments, so I am using matched pairs of 300B tubes.

Since the amp uses fixed bias, you really need a way to measure the plate current. For this, I designed some digital "panel" meters that are contained inside class tubes, which mount in an octal socket. This is another product of www.situbes.com. Of course, you can use any meter you'd like, but these look cool :)

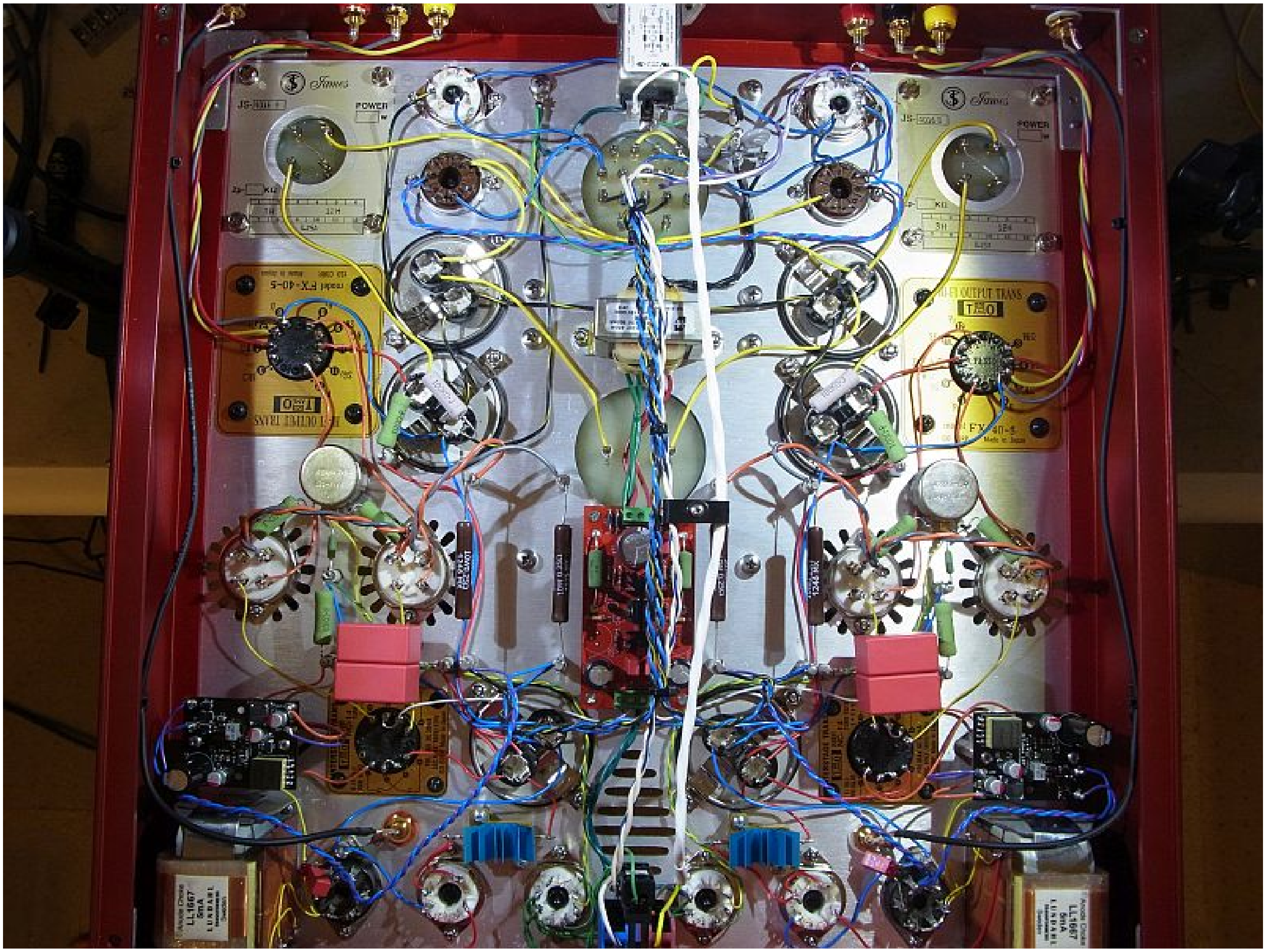
Since the driver is a DHT that is direct coupled to the input tube, the filament has to sit at a fairly high voltage. It really needs DC. You could use a standard transformer/rectifier/regulator that floats to power it. But no! Instead I designed an isolated flyback supply. It sits directly on the back of the tube socket, and convers the 6.3V heater power into isolated 2VDC for the 31 tube. It's the little black PCB that you see in the underside photos below. This module isn't available for sale yet... hopefully soon.

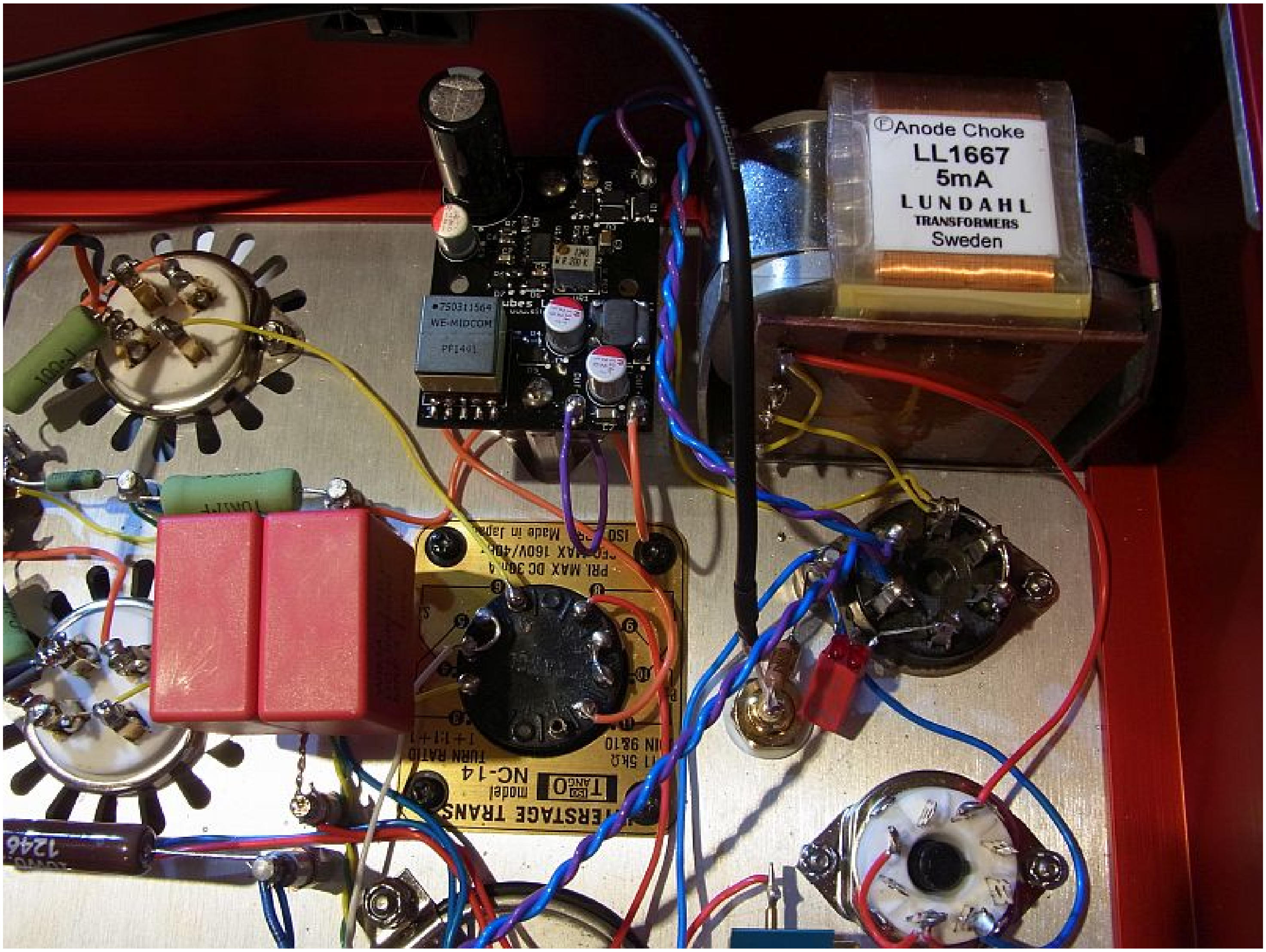
Construction

This thing is HEAVY. The chassis was made by [Landfall Systems](), and has no problem with the weight.

Wiring is standard point-to-point, other than the bias supply PCB and the driver filament supplies.

Here are photos of the amp inside & out. Click the photo for a full resolution version...




Anode Choke
LL1667
5mA
LUNDAHL
TRANSFORMERS
Sweden


James
JS-4016B
POWER
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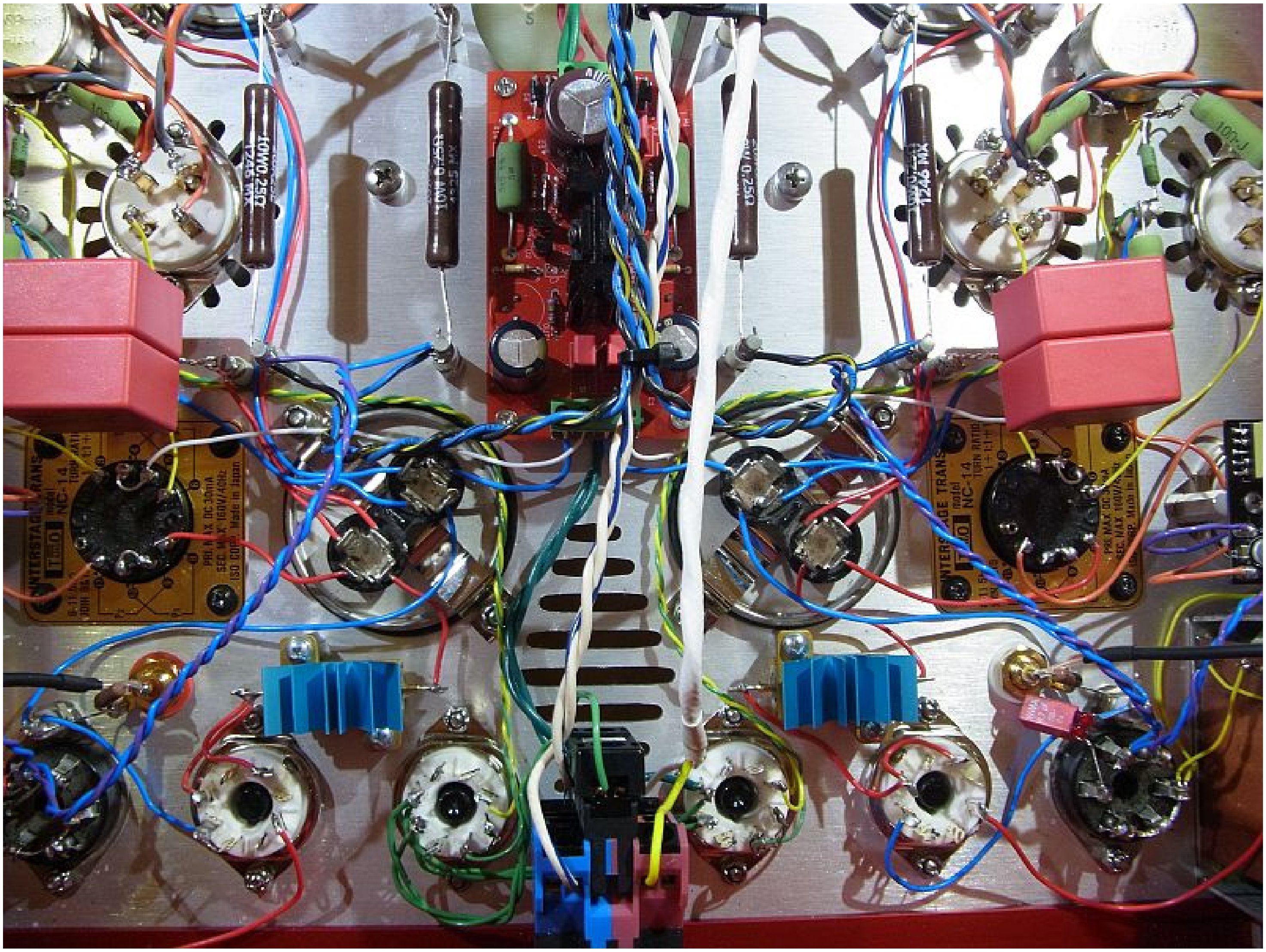
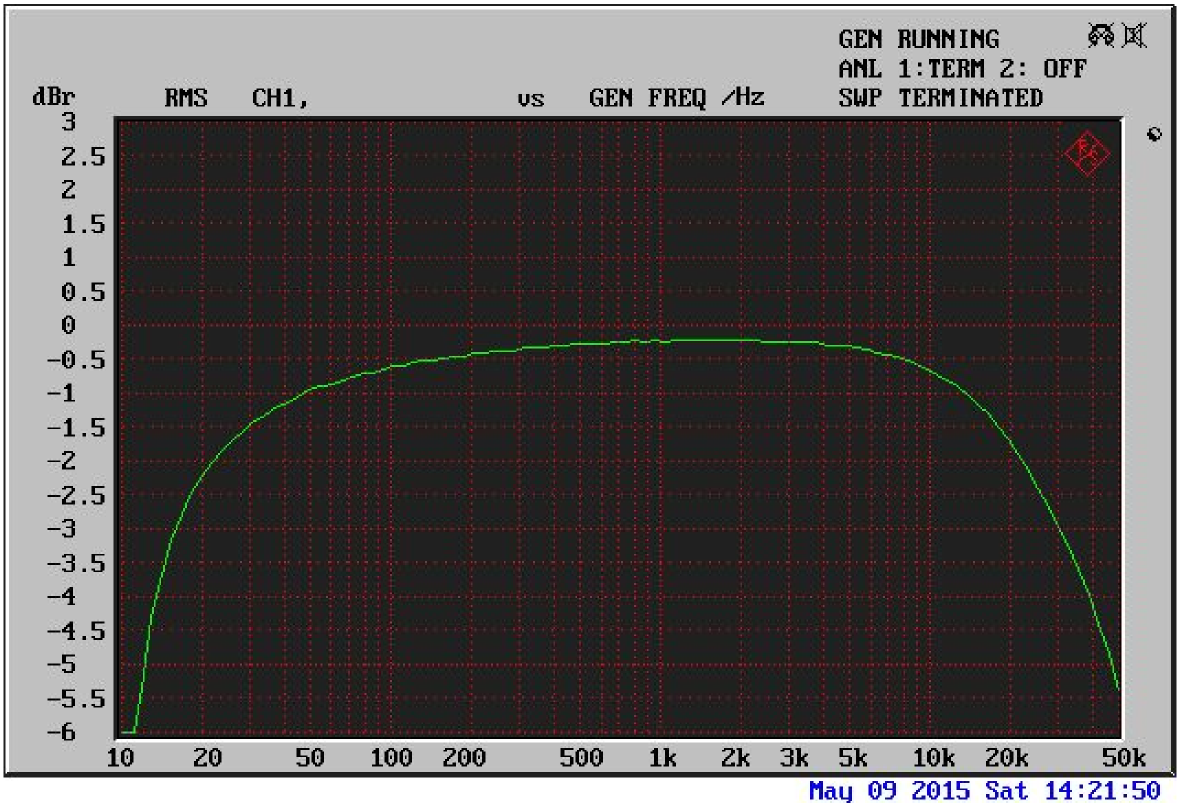
-p- KΩ
3H
12H
0.25A
HI-FI OUTPUT TRANS
TANGO
P2
16Ω
SG1
model FX-40-5
ISO CORP.
Made in Japan
100KΩ·J
100Ω·F



Measurements

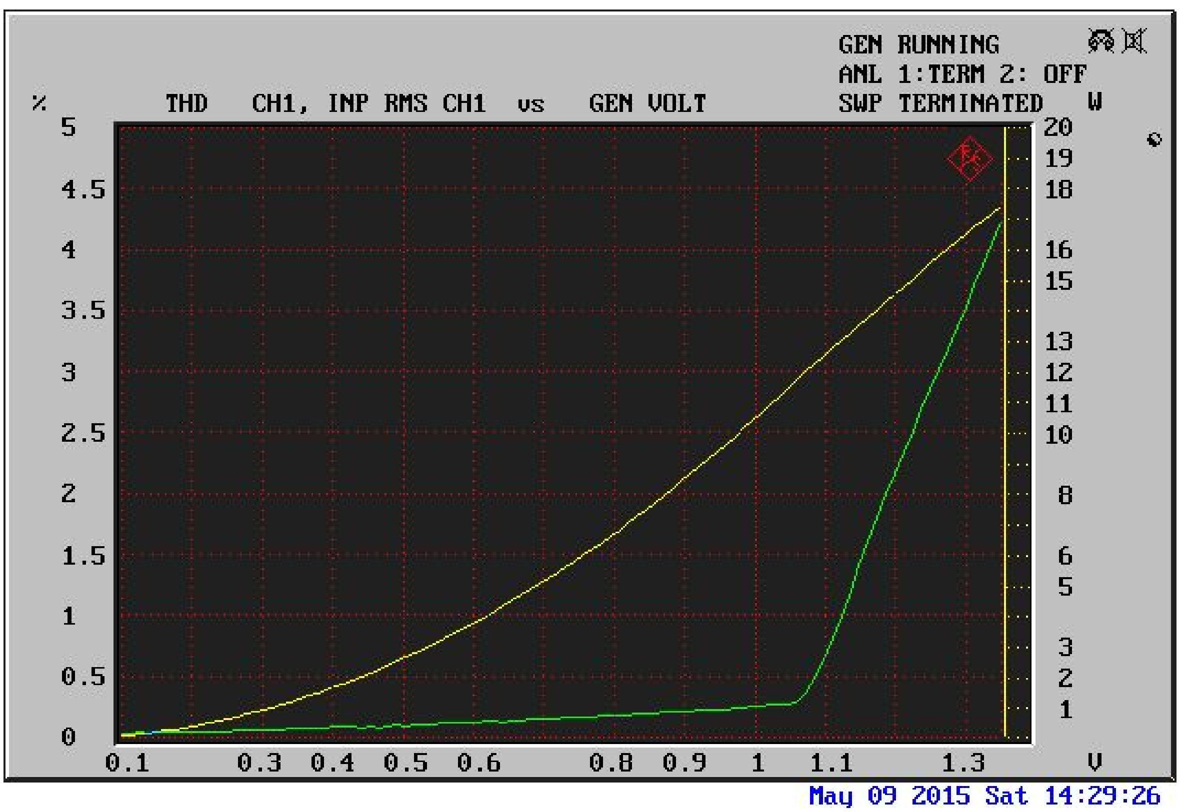
Here are some measurements of the completed amp:

Frequency response at 1W into 8 ohms:



Basically down 2dB at 20Hz and at 20kHz, -3dB at 15Hz and 30kHz. The limitation comes mostly from the magnetics - the plate choke on the first stage, and the interstage transformer, both contribute. Some might argue that -3dB @ 30kHz isn't good enough, but I think it is.

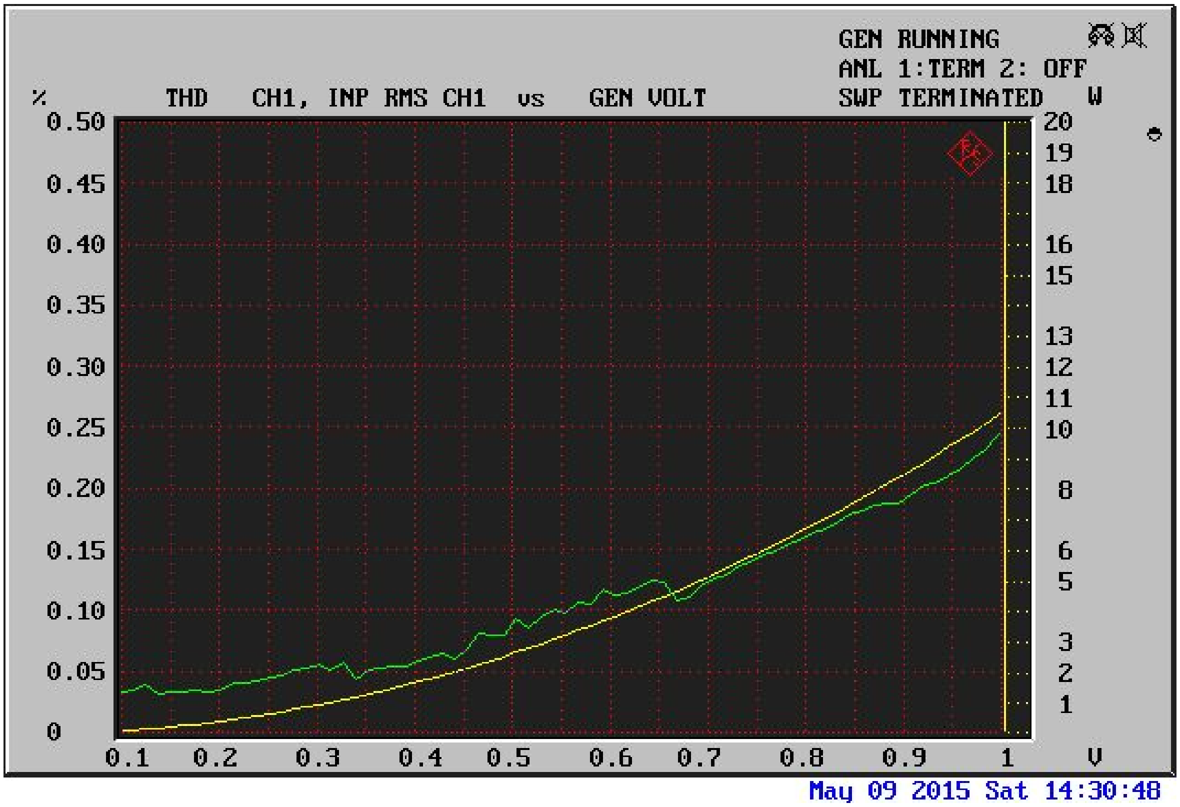
Output power (yellow) and THD (green) vs. input voltage (1kHz):



You can see we get about 12W at the beginning of clipping, and close to 19W at 5% THD. This is biased heavily into class A, at about 130mA per pair. You can bias it at higher current, but it doesn't make a big difference. You can also move it

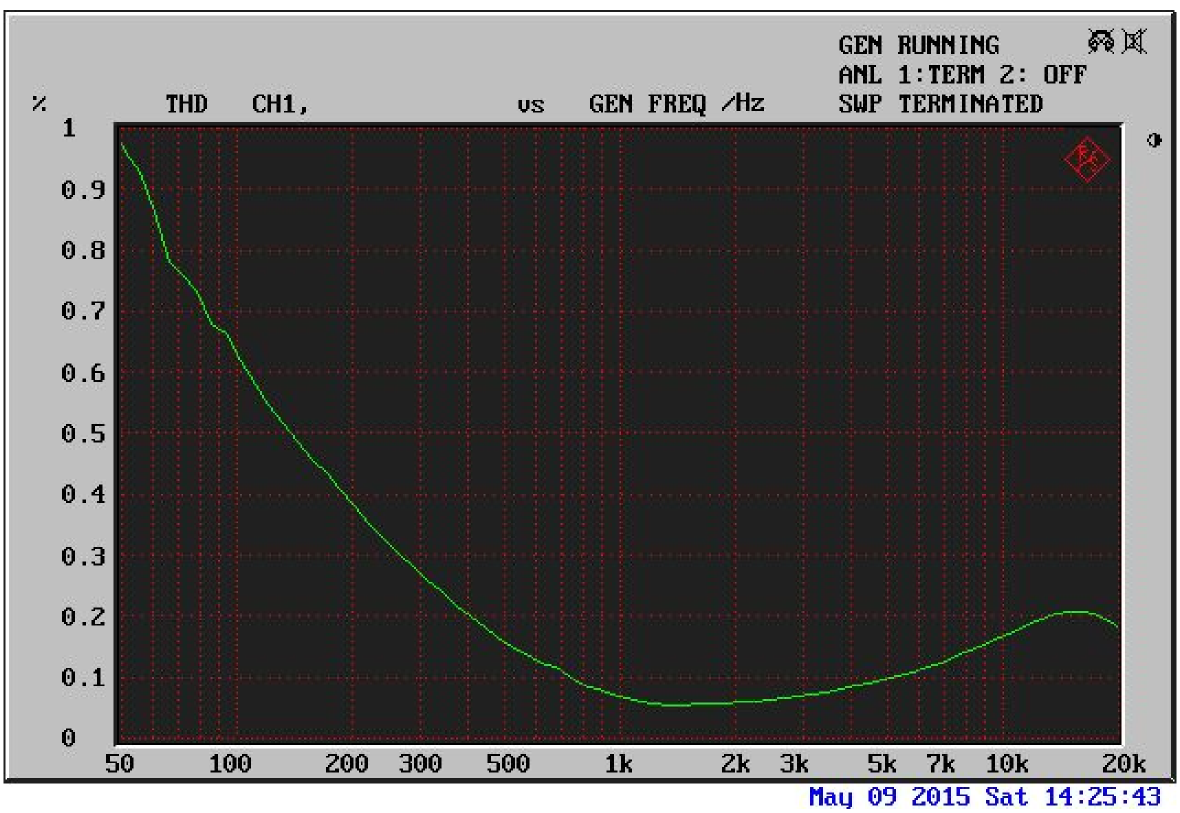
down into class AB, which increas4es power output slightly at the expense of higher distortion. Note that with the transformer coupled driver, the 300B does go into A2 operation a little bit.

Here's a zoom showing more detail up to 10 watts:



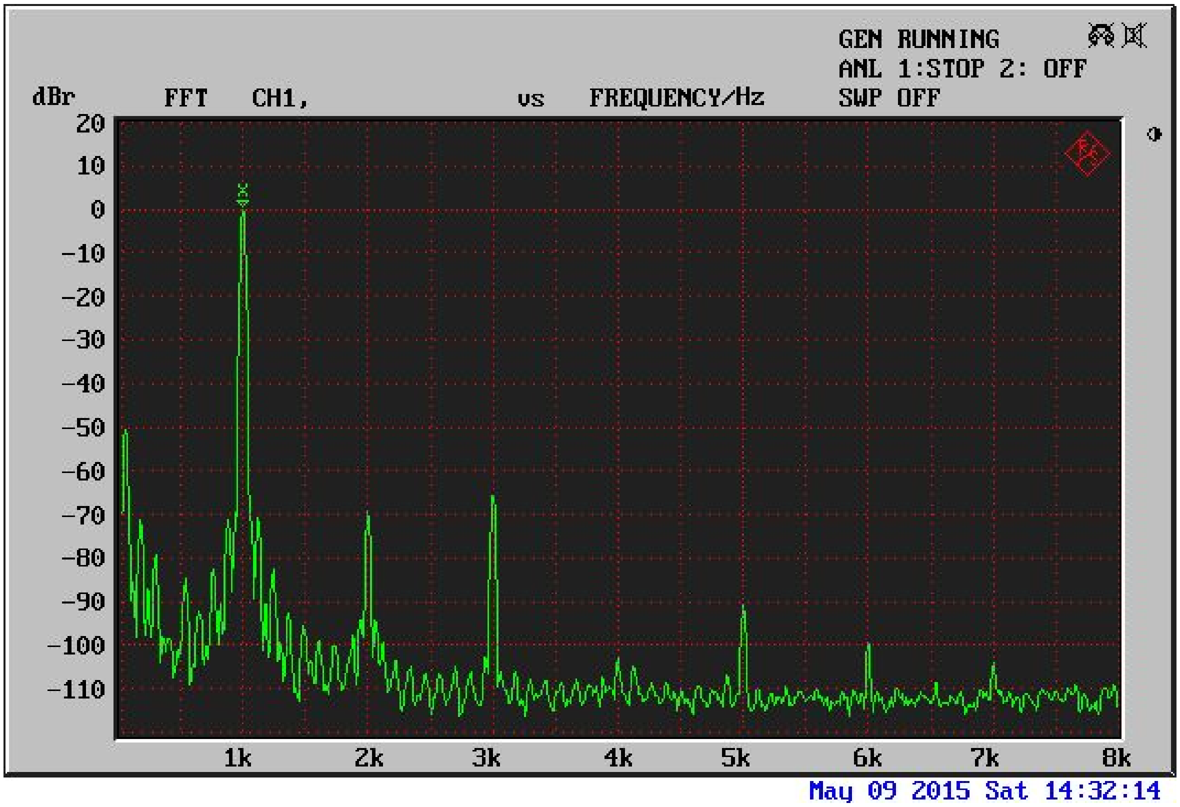
Close to 0.2% THD at 10 watts. Pretty good for zero-feedback 1930's technology. Try that with silicon!

THD vs. frequency (1W into 8 ohms):



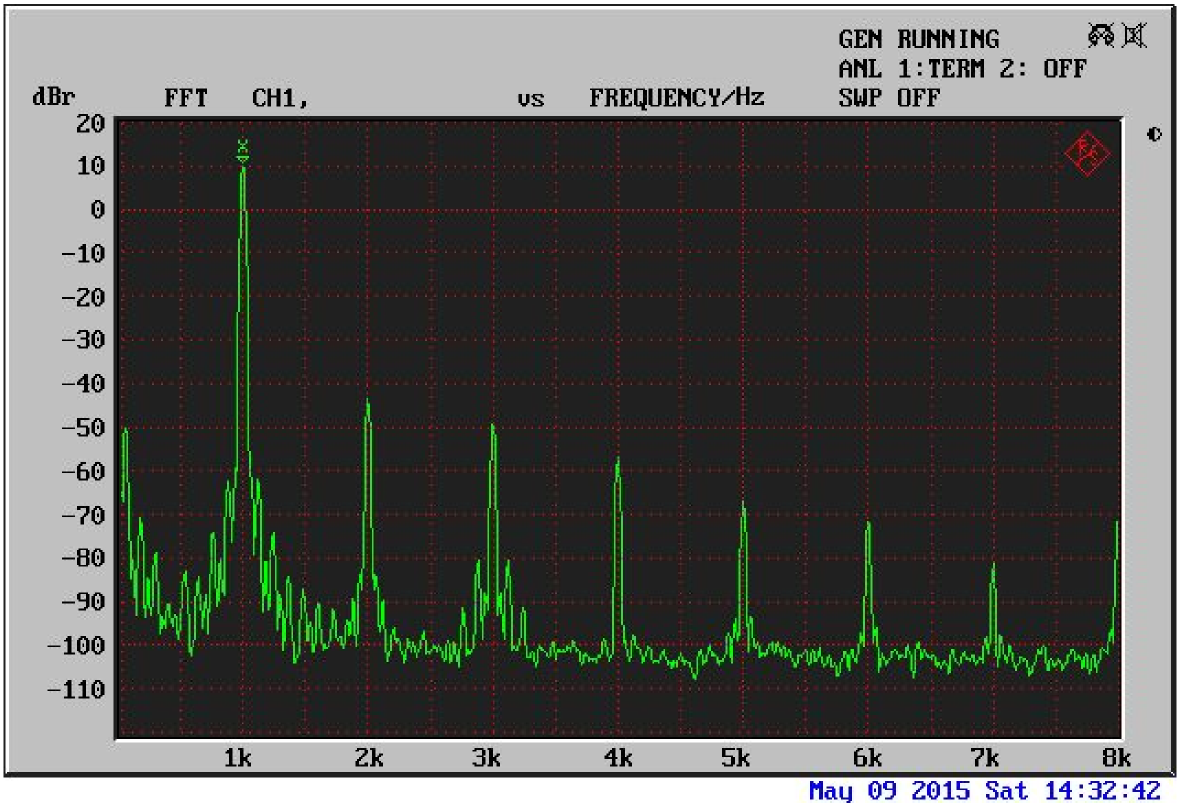
If there is a downside to interstage transformers and plate chokes (other than the expense, which is significant), it is shown here. You can see LF distortion due mostly to the limited inductance of the magnetics. At high frequencies, parasitics (mostly inter- and intra-winding capacitance) comes into play. That said, performance in the midrange, where vocals lie and the ear is most sensitive, is good.

FFT, 1kHz 1W into 8 ohms:



Here you can see the even order distortion cancellation inherent in push-pull stages. The 3rd is slightly above the 2nd. The remaining 2nd is from the input and driver stages as well as output tube mismatch. Still, both are close to -70dB. This is about 0.08% with 400Hz - 30kHz bandpass filters enabled.

FFT, 1kHz 10W into 8 ohms:



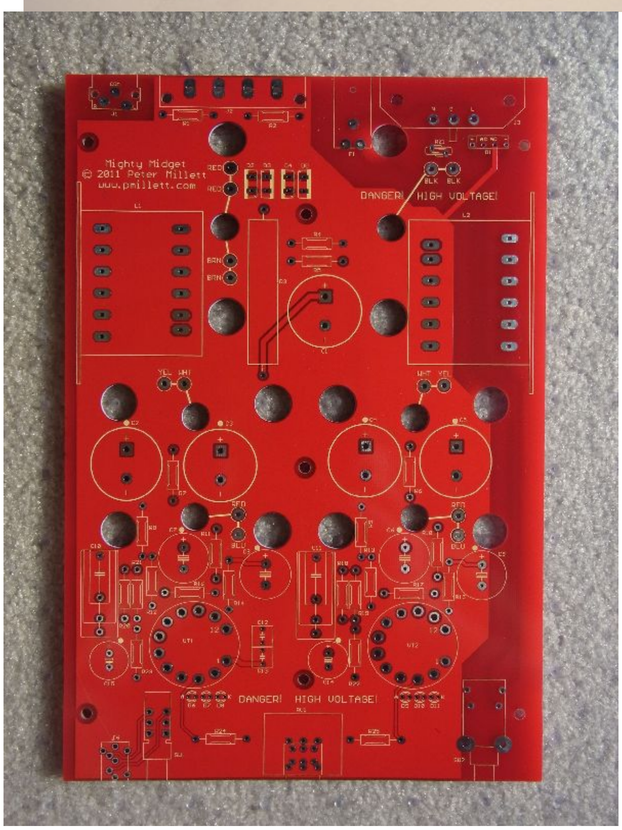
The FFT at 10W is well behaved, with a nice "waterfall" of harmonics. THD here measures about 0.2%.

[DIY Audio Home](http://www.pmillett.com)

The "Mighty Midget" (originally in AudioXpress 05/08)

I am now selling PCB's for this project. See my eBay store (seller "pmillett").

UPDATED 12/19/2011 - I've made some small tweaks to this design and put it on a PCB:



My goal in re-designing the Mighty Midget was to make it as easy to build as possible for a beginner to build. To that end, everything except the output transformers are mounted on the PCB, including the (frightening to a beginner) AC wiring. Though it doesn't *guarantee* success, it does raise the odds.

I used [Front Panel Express] to make the case for the PCB, using their side profile extrusions. This lets you poke parts (connectors and switches) out both the front and the rear of the box. I also had Edcor make a custom PCB-mount choke - [Edcor] is very good at fulfilling requests like that - so you can buy them as well as the transformers from them.

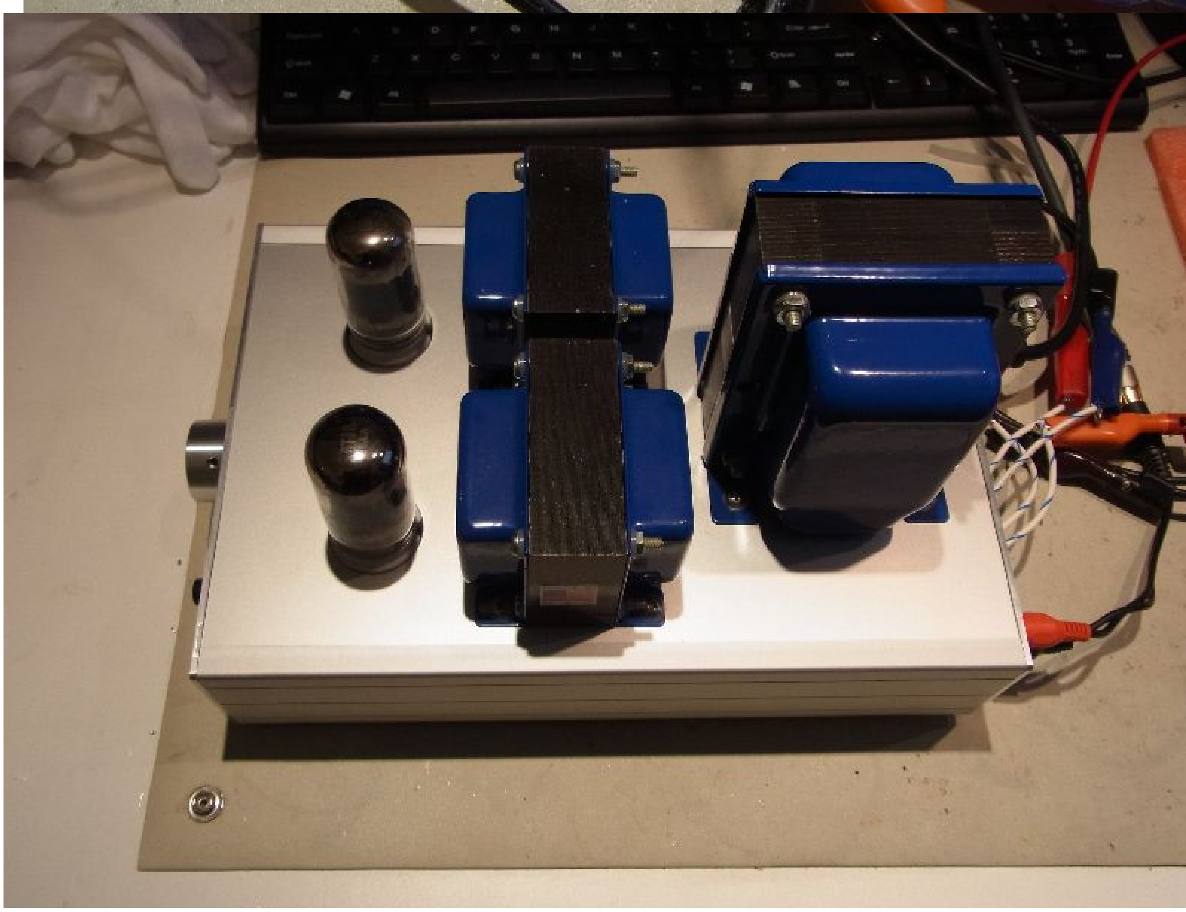
The schematic has changed a little bit. Mainly, I used a resistive divider to generate the screen voltage instead of a zener. This removes the power-down instability and squeal that forced me to add a power-up muting relay.

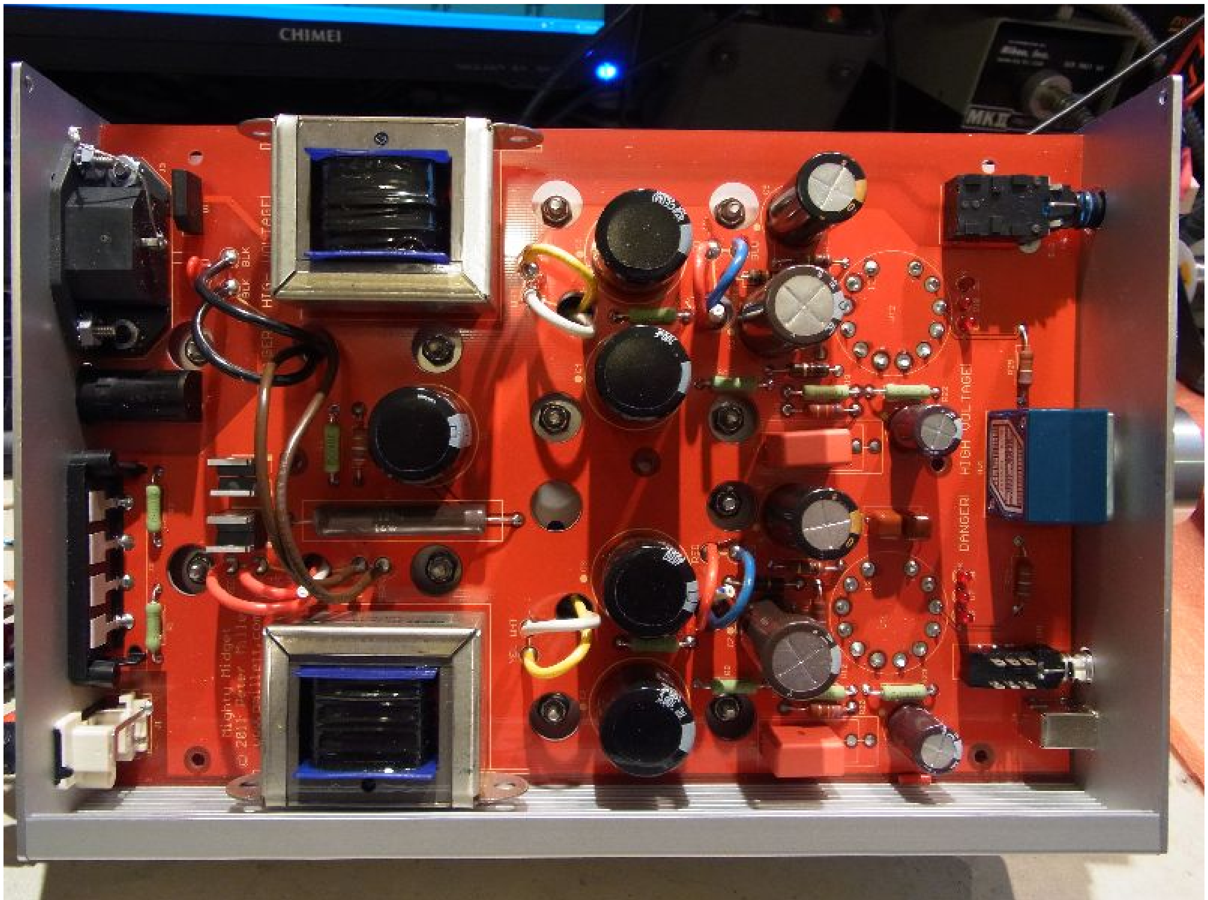
Here is the new PDF schematic, and BOM.

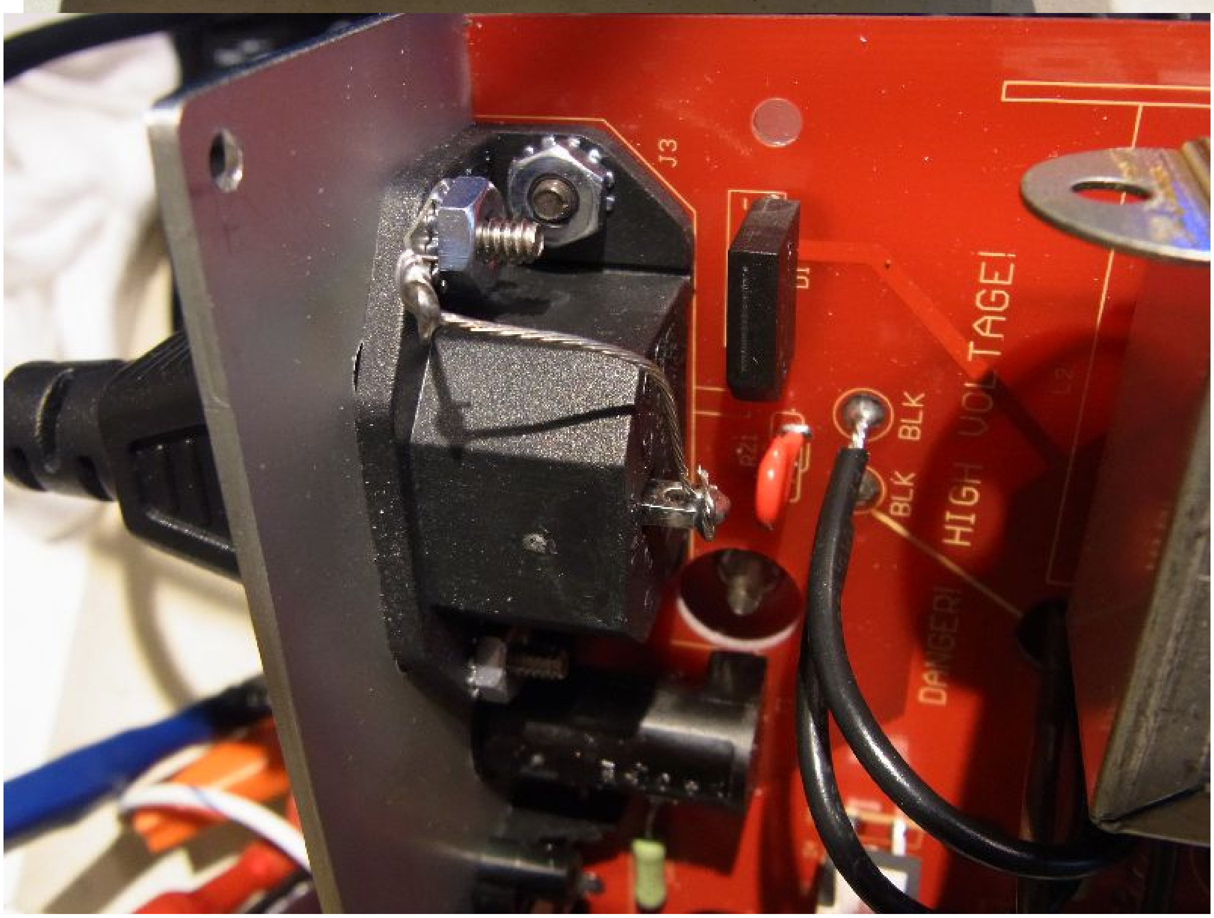
If you want to order the enclosure from Front Panel Express, you can just tell them you want to order their quote # 900825 - that will include the panels, side extrusions, and hardware. Or, you can download my FPE files and customize them (ZIP archive). (If you're observant you might notice that there is an error or two on my chassis - they are fixed in the files).

And some additional photos:


INPUT
SPEAKERS
AC POWER







Note in the last photo the wire that connects the case to ground. Turns out that this is important - without it the amp was noisy and tended to oscillate. So do ground the chassis!

As per usual, I'll sell these PCBs on eBay.

The "Mighty Midget" is a simple single-ended pentode amp that uses inexpensive compactron TV tubes. It puts out about 3 watts per channel, and uses only one (two-section) tube per channel.

This project was published in audioXpress, May, 2008.

In summary, the amp uses 6T10 tubes, which contain dual-control pentode and power beam tube sections. The dual-control pentode is used as a regular pentode amp (with a trick of biasing up G3 to get linear characteristics). The beam tube section is used in pentode mode, with about 10% plate-to-grid feedback to get decent distortion and damping factor. No global feedback is used.

With a B+ voltage of about 300V, the amp puts out about 3.5W per channel, while dissipating under 10W on the plates of the output tubes. THD at 1W into 8 ohms is about 0.7%. You can see the FFT below...

The amp has a modest damping factor, with an output impedance of 3.5 ohms or so. It turns out that this sounds really good into my inexpensive Fostex FE164-based speakers, which tend to be a little brassy sounding on a low-output-Z amp.

I used small 7k SE OPT's that I found in Akihabara (Tokyo), but an Edcor XSE-10-8-8k should work well, as would a small Hammond SE OPT.

Anyway...

Since many of the photos and details are hard to read in the magazine, posted on this page are all the photos, schematic, and mechanical files for you to build this amp. Enjoy!

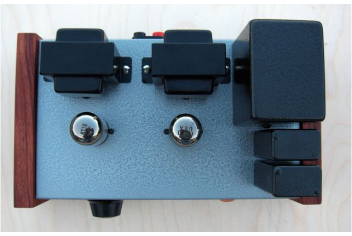
The schematic (144kB PDF file)

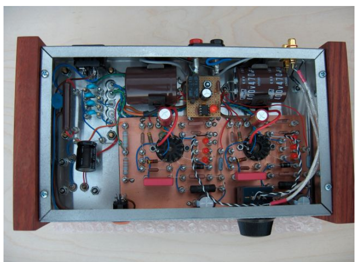
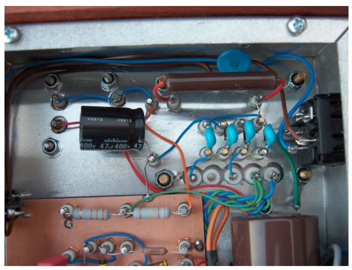
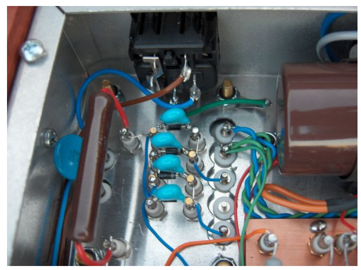
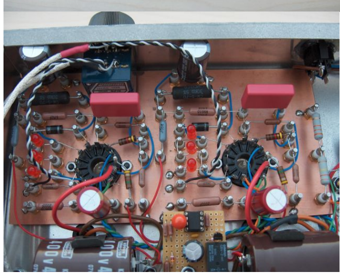
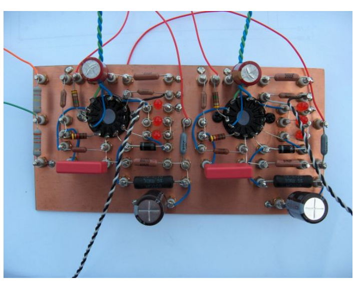
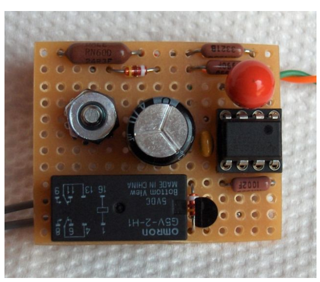
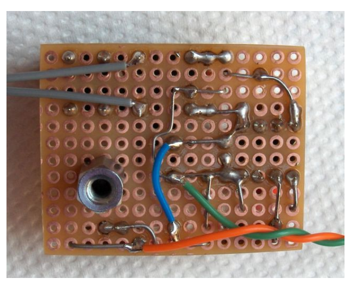
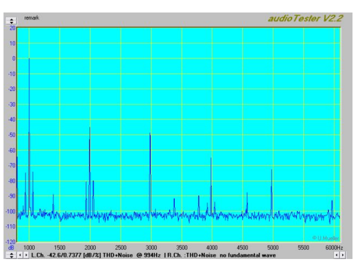
Mechanical layout:

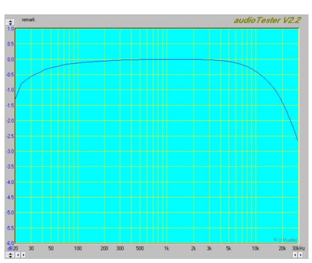
PDF of the mechanics (128kB PDF file)
ZIP archive with AutoCAD DWG and R12 DXF files (144kB)

Photos

Click on the small photos for a full-size photo in grisly detail.





Turquoise Energy Ltd. News #68

Victoria BC
by Craig Carmichael - October 4th, 2013

www.TurquoiseEnergy.com = www.ElectricCaik.com = www.ElectricHubcap.com = www.ElectricWeel.com

Headlines:
**** CMBR: Abundant, omnipresent, free radiant energy is real and it can be tapped!**
**** High energy storage Mn-Mn Batteries are working! - High self discharge drops off 'all by itself' over weeks.**

Month In Brief (Project Summaries)
- "Discovery" of free, abundant, omnipresent radiant energy: it's well known to astronomy as **"Cosmic Microwave Background Radiation" (CMBR or CMB)**. ...So *that's* what all those 'free energy' people have been groping for without being able to name it! - Other stuff - Mn-Mn battery project - More other stuff getting left behind - Thermoelectric Fridge performance update - 3D printer repair.

In Passing (Miscellaneous topics, editorial comments & opinionated rants) (none)

Electric Transport - Electric Hubcap Motor Systems
* More Mazda - NiMH Battery Tube Stuff: reduced from 3 to 2 NiMH batteries, increased them to 90 AH each.
* Front suspension adjustment (it adjusts!) - new brake pads & shoes
* **Cable to monitor any single battery**: uncovers 2 unexpectedly weak batteries... that tested 'okay' when the car wasn't going.
* Replaced: 2 "new" ("reconditioned") batteries increase range & reserve (8-9 miles/13-15Km?)
* Quick defoggers: small 12v heater-blower dies fast with small battery. 120v hair dryer before starting works well, windows stay clear surprisingly long.

Other "Green" Electric Equipment Projects (No reports)

Electricity Generating
* Vertical axis wind turbine from PVC pipes, my motor shafts & bearings, lawnmower motor as generator. (Sigh, not finished)
* VLF Radio Wave/power line waves Power Pickup unit: made one - little bang for the buck.
* **"Space Energy", "Zero point energy", "Vacuum energy" etc, etc... Really means CMBR !?! - Wow!**
* CMBR = "EHF" radiant energy, between microwave and far infra-red bands, centered on 1.8mm, 160 GHz.
* CMBR is "omnipresent", comes from all directions, and penetrates Earth's atmosphere.
* **CMBR constitutes "most of the radiant energy in the universe".** (Wikipedia)
* Tesla, Moray, Markovitch, and quite a few others: CMBR energy pickups/converters/electrical generators?
* Simplest pulsed coil "TPU" CMBR harvester - has been replicated by third party.
* Dropping other electricity generating projects? - Geothermal.

Electricity Storage - Turquoise (MnMn) Battery Project etc.
* The high self discharge gradually drops off (maybe ceases?) by itself over a period of weeks. All you need to do is wait!
* **Mn-Mn, permanganate-manganese, batteries may now be considered to be working!!!**
* They can be used from 2.5 volts and gradually drained down to as low as 1.5 volts without damage.
* The negode appears to remain more negative than zinc for the entire discharge (so theoretically the zinc current collector and zinc powder additive won't corrode) - it's more the poside that loses voltage.

* Utilization of active substances and performance could still be a lot better.
* Improved **soldered NiMH dry cell battery packs**. (well... improved over my previous techniques...)

No Project Reports on: DSSC solar cells (will probably abandon), LED Lighting, Pulsejet steel plate cutter, CNC Gardening/Farming Machine (sigh, maybe summer 2014?), Woodstove/Thermal Electricity Generator (will probably abandon), Peltier & vacuum pipe heat pumping, Ultra-efficient torque converter transmission, individual EV battery monitor (will probably cancel).

Newsletters Index/Highlights: http://www.TurquoiseEnergy.com/news/index.html

Construction Manuals and information:
- Electric Hubcap Family Motors - Turquoise Motor Controllers - Nanocrystalline glaze to enhance Solar Cell performance - Ersatz 'powder coating' home process for protecting/painting metal

Products Catalog:
- Electric Hubcap 4.6KW BLDC Pancake Motor Kit
- Electric Caik 3KW BLDC Pancake Motor Kit
- Sodium Sulfate - Lead-Acid battery longevity/renewal
- NiMH Handy Battery Sticks, 12v battery trays & Dry Cells (cheapest NiMH prices in Victoria BC)
- LED Light Fixtures

(Will accept BITCOIN digital currency)

...all at: http://www.TurquoiseEnergy.com/ (orders: e-mail craig@saers.com)

September in Brief

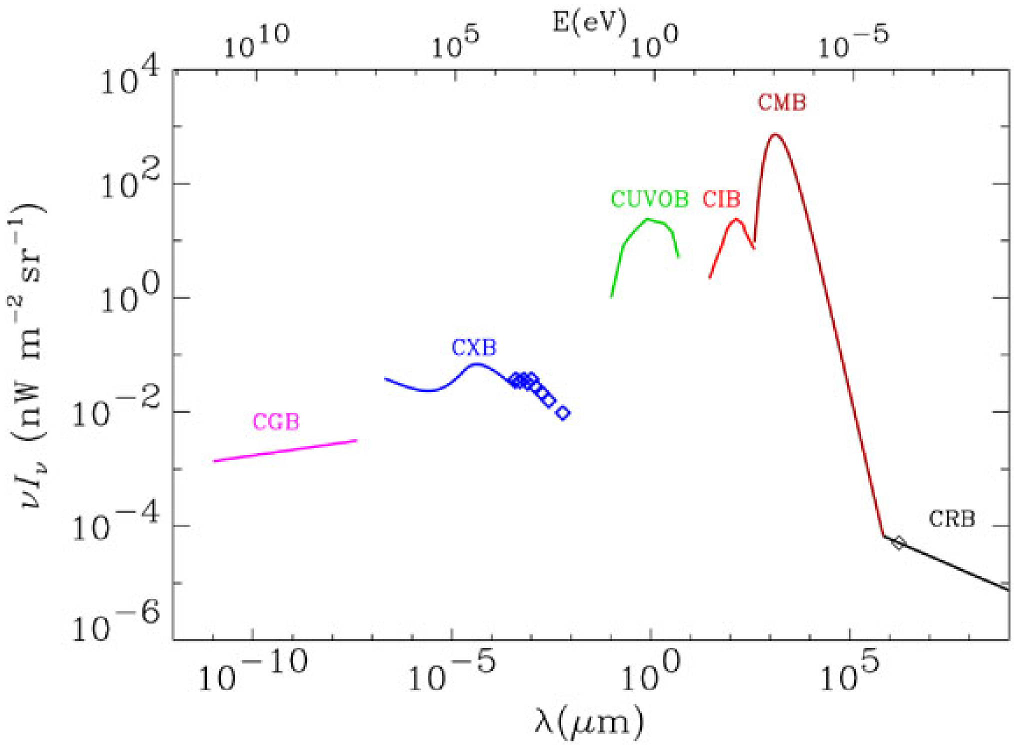
CMBR

A fantastic development occurred in September. I saw the term "space energy" that we should be able to harness easily, from a source I deem credible. I started thinking about all those vague, undefined and unexplained terms people were using: "vacuum energy", "source energy", "zero point energy", "radiant energy", the "cosmic carrier field". Skepticism and incredulity about such things is inevitable when none of the proponents of such ideas are able to identify any source of such energy.

As I looked into possibilities, somewhere my mind made a seemingly obscure connection: I thought of the "cosmic microwave background radiation" ("CMBR" or "CMB"), well known to astronomy. Every time CMBR is mentioned, the next phrase is about how this radiation is "left over" from the supposed "Big Bang", and hence "is evidence for" this specious theory about the start of the universe. It sounds so trivial. AFAIK it's never been discussed for its own merit or in any other connection, still less ever mentioned as a potential source of energy. In Wikipedia I read through many paragraphs of this, but found a few gems buried within all the blather. The best one was this: "**Most of the radiation energy in the universe is in the cosmic microwave background**." Bingo! This was what all those vague "free energy" buff terms were groping at. There is indeed a free radiant energy other than sunshine, available throughout the universe, and this was it.

The CMBR has some interesting properties. It's called "microwave", but its frequency band in the electromagnetic spectrum is five octaves above the "microwaves" used in microwave ovens, the center wavelength being around 1.8mm rather than several centimeters. (So... why are they called "microwaves" rather than "centiwaves"?) That's much greater than the difference between ultra-violet and infra-red, which have considerably different radiative effects.

The CMBR penetrates Earth's atmosphere to the ground, but it obviously doesn't cook everything or kill life. It seems to be all around yet unseen and having no notable effect on anything. Being a few octaves above typical microwave frequencies and a few below the far infra-red, it occupies its own unique frequency band in the electromagnetic spectrum.



Apparently, the energy available from CMB rays is perhaps 50 times
as strong as that from sunlight - or from any other radiant energy.

Knowing that there actually is a radiant energy available, and that the likes of Tesla and a fair number of other more recent inventors have managed to turn it into electricity - and seemingly abundant electricity - puts a whole new complexion on trying to harvest "free" energy, and a whole new focus on what might be best for me to attempt to create next. Energy saving devices and greater efficiencies, while valuable, take a second place to the likelihood of being able to make very substantial levels of electricity on demand, day or night, in any weather.

Techniques and circuits for harnessing this energy aren't entirely trivial and obviously from the many terms describing it, it hasn't been very well understood even by those who've successfully made electricity from it. Tesla understood it was "radiant energy" he was harvesting, and someone recently told me that in addition to lighting light bulbs, Tesla drove around a Detroit Electric (electric car) with no batteries, using his energy receiver for power. This is an amazing story I hadn't heard before. Others have said it was "EHF" energy, but again without naming a source for that energy.

So far it seems that all such technologies have been ruthlessly quashed by the gangster-parasites who have controlled our society, before much how-to knowledge about them spreads, with typical stories of vandalism and threatening, beating and probably murder of the inventors over the decades. The US patent office even "lost" a patent for a working 50KW device in the 1930s.

As the days went on, every thought and conversation about solar collectors, wind power, efficiencies and effectiveness of systems, and the ubiquitous topic of batteries and vehicle range, became a graphical illustration of what a game changer free radiant energy would be: electric camping stoves and coolers, quiet electric cars and buses with unlimited range, electric trains with no overhead wires or electrified rails, quiet electric aircraft, power for spacecraft, the speedy end of gasoline powered vehicles, eventual elimination of ugly overhead power lines and electric bills... and doubtless I've missed many more subtle improvements to our lives.

These are a few of the things we've been missing out on for many decades because our society has tolerated fear, greed and corruption and somehow allowed ruthless gangsters and their sycophants to rise to the positions of power and influence and run roughshod over us and over our real elite: those with ideas, ideals and drive for making a better world! What could our world be like if these people were in charge instead?

But the day is almost upon us that the inbred family cliques who today control 80% of the world's

economy will have no more power to force everyone to buy their dirty energy products and live lavishly off the backs of the productive. The internet is starting to expose their dirty little secrets, and the coming financial collapse will eliminate their power bases. And some of them are even now changing their own attitudes and beginning to realize that not only everyone else but they themselves and their children will live better, happier lives with a reframing of our society and its institutions as well as long overdue energy technology advances.

I've decided to go ahead with a relatively simple demo unit based on a 2007 "open source" design that was apparently duplicated by another party from the PDF instruction file. It has a double ring 'collector coil', three 'control coils'/transformers at 90° to the collector loop for magnetic interaction, and a rather complex and poorly understood driving circuit of two or three independent sharp-edged square waves at frequencies in the x100 s of KHz range. Probably in the complex interactions and harmonics of these distributed signals is hidden some heterodyne (beat) frequency that converts 160 GHz to some far lower frequency that flows through wires, and that electrical and electronic devices respond to.

My start at a CMBR energy harvesting/collecting/converting unit. The secret is doubtless more in the control frequencies and driving electronics than in the exact physical configuration. (The yellow iron-powder cores are for the control coil-transformers, which have yet to be wound.)

Shortly before I got onto CMBR, I had started thinking about resurrecting an ocean wave power project with the highly effective, safe, economical design I'd seen last December (see TE News Dec. 2012). A fixed tower installation by the shore would need to be built if it's to be properly tried, and it should be properly tried if it's to be tried at all, or else the skeptics will point to one more failed or marginal attempt to harness a new energy source and it'll be doubly hard to try the next time. But at what point does one make an approach for support with an untested idea?

On the other hand, what is a million dollars in research & development investment if it proves the same power can be made for 2 or 3 billion dollars instead of the 8 billion or more for the Site C Peace River dam, and done in incremental stages instead of the "all or nothing" dam?

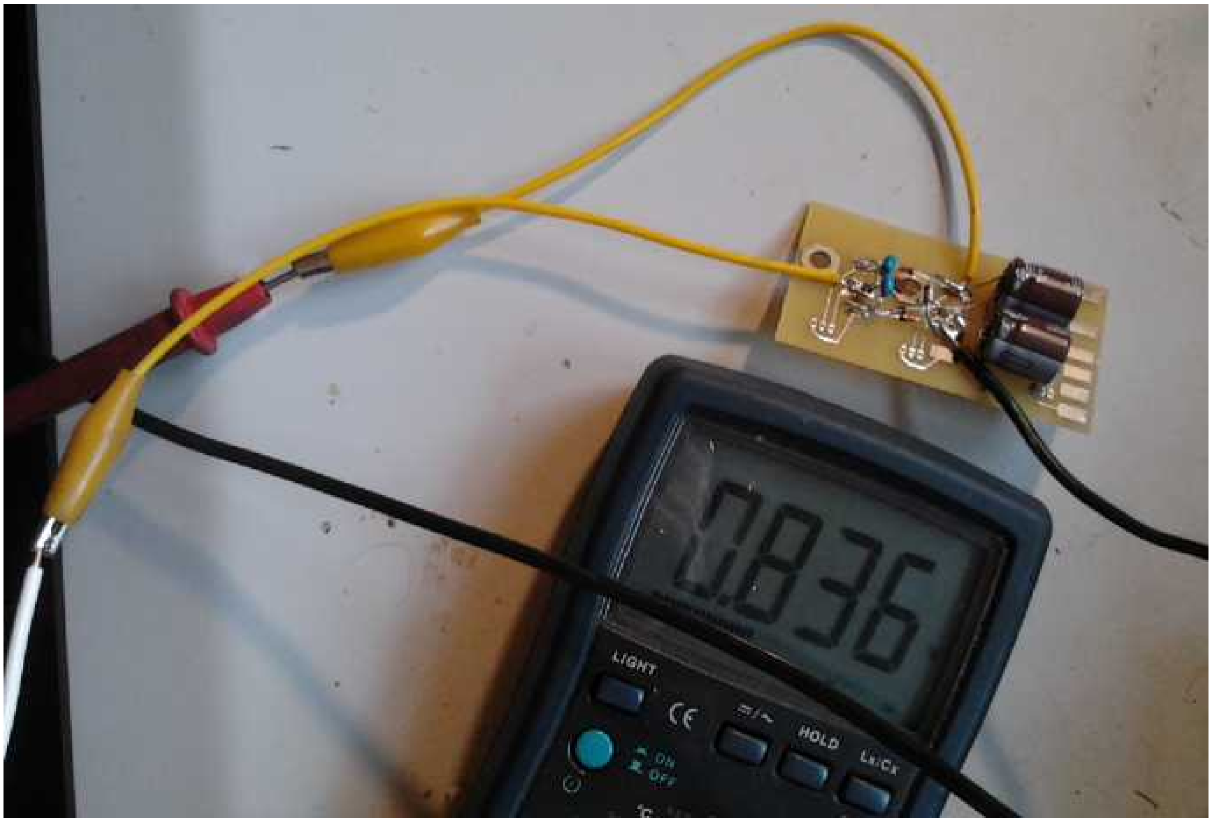
About the same time, as a personal power making project, I cut 8 vanes for a simple vertical axis wind turbine ("VAWT") from PVC pipes I already had, and formed them into the apparently optimum "J" shape, softening the plastic in the oven at 250°f. This could mount in the attic of the house when completed, with just the turbine part above the roof peak, via a small hole in the roof for the shaft. The DC lawnmower motor planned as a generator would feed the low voltage box in common with the

solar PV system -- which virtually stopped producing later in the month as clouds and rain set in.

Layout for the vertical axis wind turbine.

I also made a little circuit I saw on line that harvests low frequency radio and powerline waves, reputed to be able to charge cell phones. I only got a volt out of it, and no measurable current. (It probably works best with the antenna right next to an electrical cord of an appliance drawing a lot of current.) A tuned circuit - tuned to the strongest AM radio station - should do better for radio waves. There wasn't much "bang for the buck", but it did demonstrate picking up radiant electromagnetic electricity out of the air.

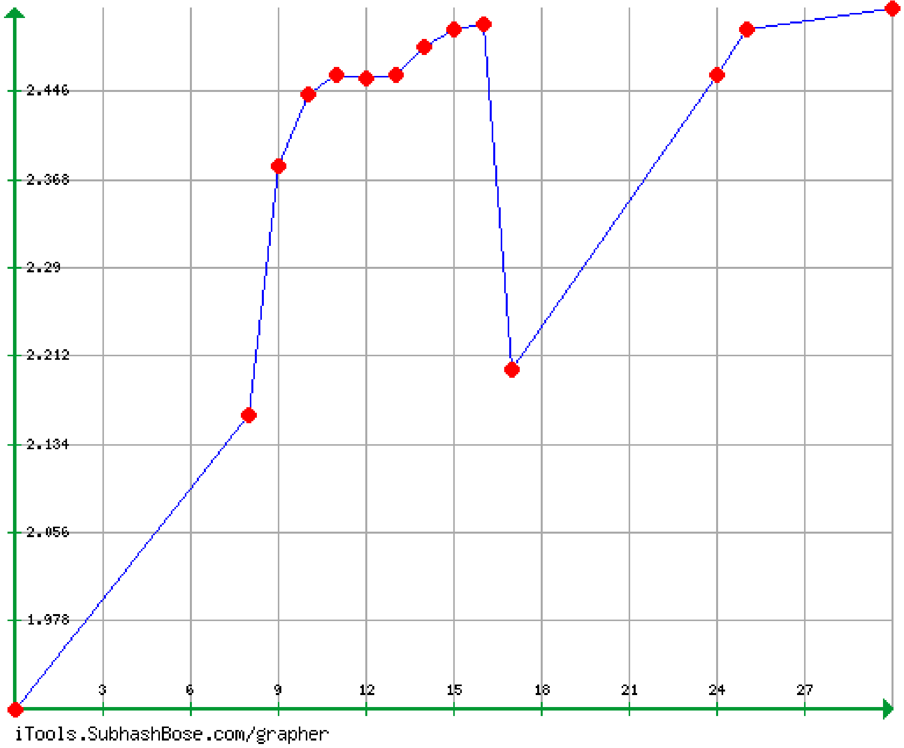
After the ocean waves, wind turbine, and radio energy harvester, I found the CMBR and it seemed like a better thing to invest my time in.



"RF Energy Harvester" circuit connected to 10' antenna wire - here up to .836 volts and slowly rising.

Another major development was that the battery made in August, "PJC1" (Plastic Jar Cell 1), gradually started holding more and more charge longer and longer. That this would happen could only be hinted at in my previous short lived cells. In August I identified the self discharge process and the logical conclusion was that my chelation idea wasn't working well enough to use. Still, they seemed to slowly improve, and finally I have a cell that's lasted long enough to see the process continue for a while - I won't say to complete.

It does seem it just needs time and charging to gradually take effect. Seemingly, all one has to do is charge and wait for good performance. It might take 2 or 3 months to reduce the discharge to "trivial" levels.



Improving charge retention with time, with a 'reset' when I opened the cell and made a change.
(Y: cell voltage after ~8 hours; X: September date)

A possibility for a swiftly ready cell would be Ni-Mn at "moderately alkaline" pH, but further tests on that combo at pH 14 in a Changhong cell showed that the Mn doesn't seem to hold a charge, even in the fridge. If it can be made to work, I haven't proved it yet. At lower pH it should work, but it won't have the higher amp-hours of Mn-Mn. And I haven't actually tried it yet.

I also made up a couple of soldered Ni-MH dry cell battery packs, there being no other way to fit the cells in place. However, I made two great improvements to my previous soldered packs:
1) I cut pieces of tarpaper and wrapped each cell. If the cells get overheated and melt the thin plastic sleeves, they won't short together and the pack go up in smoke.
2) I soldered them together with some flex: curved lengths of #16 stranded, insulated wire, instead of the solid, heavy "bus bar" pieces that were gradually breaking loose their solder joins with vibration in my previous soldered packs.

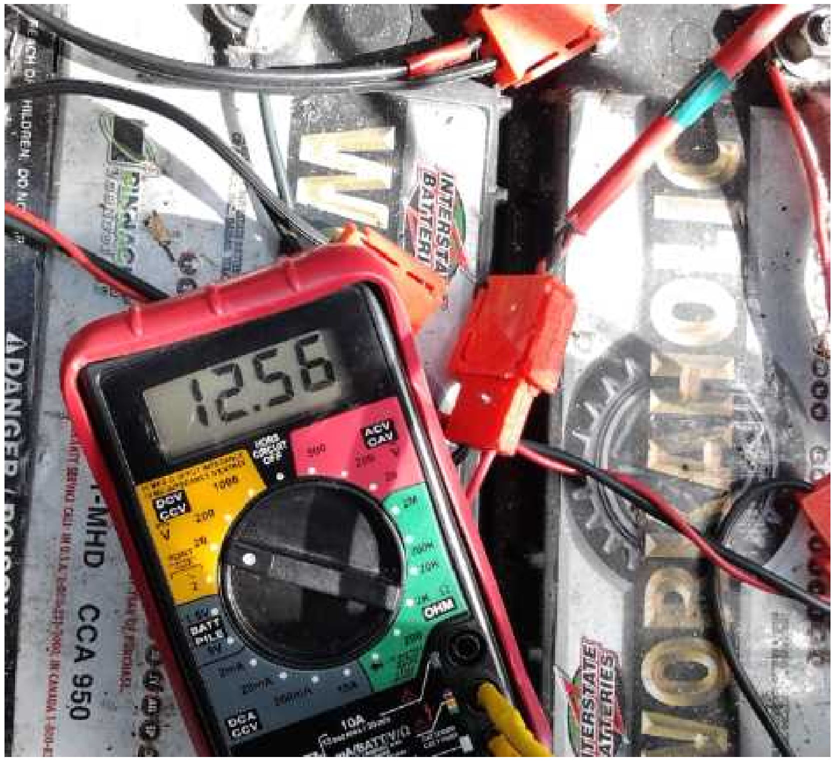
I trust the new packs will be safe and last long.

A view of a 12V, 20AH soldered pack, one of two for a 24V cordless lawnmower.

And of course I did a few things to improve the electric Mazda RX7 and keep it running. I got the front-left suspension up off the bottom, and changed the front brake pads, which were worn right down and had started a grinding noise. Defogging with a hair dryer before starting seems to keep the windows clear for the duration of a trip.

I didn't make a monitor to monitor and display every individual battery while driving, but I did make a cable to plug any one battery into a voltmeter so it could be watched while driving - just unplug its charger and plug in the meter cable. This disclosed that a suspected battery was okay, but a couple that seemed okay when the car was stationary had to be replaced. The replacement improved the range to the best yet, probably 8 to 10 miles. So far I've only gone 7.0 without a charge, but it seemed to have some range left. Anyway, best to have some reserve to retain longer battery life. Five of the nine Pb-Pb batteries now have sodium sulfate to improve their life span. The others are either "sealed" types or are at mid-life, a time when it's inadvisable to add it.

Of course removing the batteries and putting in a CMBR energy receiver(s) for indefinite range would make an individual car battery monitor unit obsolete, so again my time is probably better spent doing the CMBR project. If I make good progress on that, I'll cancel the battery monitor unit project entirely.



CAT plug to voltmeter pins cable allows watching suspect batteries while driving, tho only one at a time.

Other projects continue to get left behind. The pulley for the Sprint car transmission has sat on one side of the workbench all summer, no new LED globe lights have been made, and (even having bought the desired threaded end stoppers in August) I haven't evacuated a pipe to try improving the thermoelectric fridge and eliminating the fan. (Fridge performance update: I've been letting it run 24 hours for a while, and in the cooler weather the outside of the melting ice tray has frosted up and it's 1°c at that end of the fridge, and 7° at the top at the far end (the lowest yet). Occasionally I leave it off at night and some of the ice melts, cold side temperature rising to 4 or 5°.)

After a last attempt to get the 3D printer working again which produced only a scary (but fortunately curable) failure of the netbook computer when I plugged them together via USB, I ordered a replacement "Melzi" 3D printer control circuit board. It hadn't arrived by month's end.

Electric Hubcap Motor Systems - Electric Transport

More Electric Mazda stuff:

Individual battery monitor, battery replacements - NiMH Battery Tube Stuff - Low front suspension, brakes - Quick windshield defogger?

Batteries

I finally considered that if the NiMH batteries seemed to be the ones limiting the driving range, probably by not getting fully up to 14.0 volts and a full charge, and now having instead overcharged and damaged some of the cells with the new charger taking them over 14.0, that I would drop one of the NiMH batteries from the car, leaving room to expand the other two from 70 AH to 90. (One drawback: it now needs quite a long wire to connect from the far end of the NiMH tubes to the next battery in the string. But the extra long #2 AWG wire that I happened to have handy doesn't seem to get warm. Another drawback is that I can now fit only 11 batteries again instead of 12.)

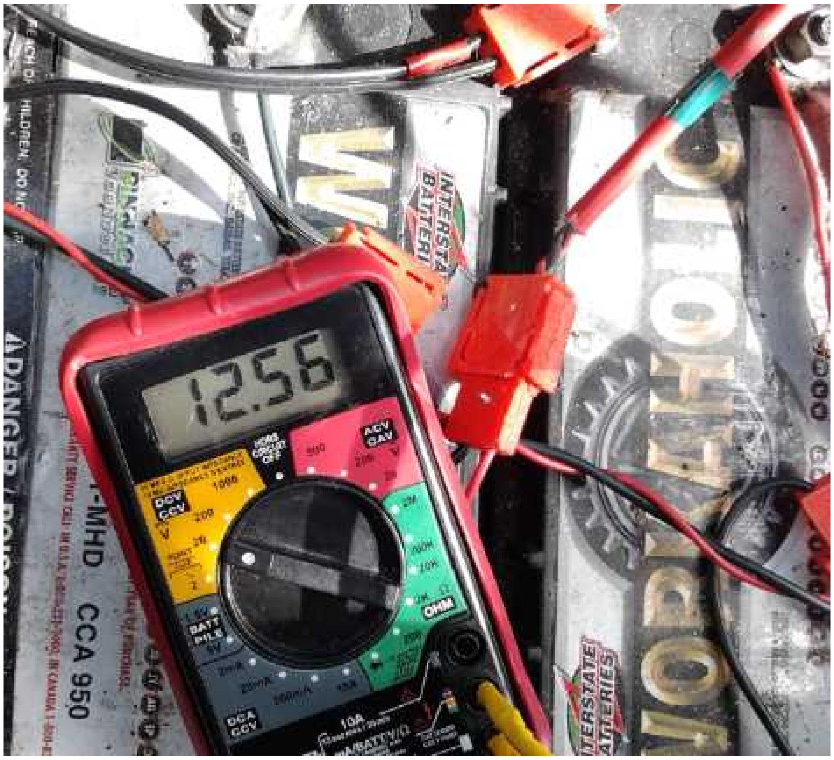
I know the available amp-hours drops considerably at the sort of high currents needed for a typical electric car, but it seems almost incomprehensible that I can only drive 10 or 12 amp-hours of distance from batteries rated for 70 or more amp-hours. In disassembling the NiMH batteries, I discovered that yet another tube had come unglued and probably wasn't contributing - just a small piece of the answer. It was the "+" end as always, leading to the thought that I invariably glue on the "-" end first and set it aside to harden. The "-" ends have been 100% reliable as best I can recall.

When I do the "+" end, I push on the end cap by hand to put some tension on the battery connections. This probably means it gets moved around a bit while it's hardening. So, new procedure: put a weight on the end to apply the pressure and don't move it until it's solid. Actually that's the original procedure... I just put the awkward weight jig aside somewhere and stopped using it - I guess I got lazy, and I didn't think it mattered. Evidently it does.

With the two remaining NiMH's now at 90 AH each I went 6.8 miles/10.9 Km on one charge on the 10th, using 16AH. (That's 16 * 132 volts = 2112 watt-hours.) One NiMH and one PbPb were pretty much down to 12.0 volts. The other nine could have gone farther, and 2 or 3 of them were still like unused (12.7+ volts) and obviously could have gone much farther. It would seem those are the sort it needs for real range. In the meantime the one lead-acid should probably be replaced and the one NiMH should have slightly higher charge voltage applied or maybe some of the sets of cells should be replaced.

I still ask, why do 80-95 AH batteries only give 16 AH of driving? One can't hope for anything like 80 at high discharge rates, but why not 25 or 30?

Individual Battery Monitor



If I haven't been able to get going on the microcontroller ciruit to have bar graphs for each battery's voltage, I could at least make up a fairly long adapter cable from a CAT socket to voltmeter pins, to check one battery at a time while driving, with the meter on the dash or passenger's seat, and perhaps get some answers to the above question. For batteries with only one plug, I simply unplug the charger and plug in the voltmeter for the test. This shows a real advantage of having standard 12V plugs & sockets, ie, the "CAT Standard". Of course, large aligator clips onto the battery posts would probably work okay too - at least for the batteries with posts.

This did indeed give answers. When the overall voltage started dropping rapidly, after only 2-1/2 miles by the time I made the cable, I found two identical PbPb batteries labelled "Workaholic" that read fine when not under load, but one dropped to about 7 volts and the other as low as -2 volts when I pressed the accelerator while driving. Somewhat unexpectedly, those were the ones now limiting the driving range. These were donated by Jim Harrington and I'm grateful I was able to use them for some months. But they're 'sealed' cells so I don't think they can be renewed.

Replacing them with earlier 'renewed' batteries only made it worse. One 'deep cycle' one that I had previously been using in the car for a while dropped seriously in voltage under load, eg to 8 or 9 volts, even when it was fully charged - it simply couldn't handle high currents. I had been unaware of that all along. There was virtually no way to know it without an individual reading while driving.

So I bit the bullet and bought two "reconditioned" batteries which were quite new and put them in. The first test drive of 3 miles showed less voltage drop. Then, since they were both still quite new, I put sodium sulfate in them.

The two remaining NiMH batteries, now expanded to 90 AH but which I was still worried about, tested fine. Probably now the range is limited by the two size 24 PbPb batteries that are at the front-left where two size 27's won't fit. However, a 7.0 mile drive showed there was still some reserve, so it'll probably go 8 to 10 miles now if I need to stretch it that far. But it's better for the batteries to have the reserve and not discharge them to the max. It's still an "in town only" car.

Suspension

I got the left front suspension cranked up off 'bottomed out'... literally. Under a plastic center cover, there's a nut at the top of the strut/shock absorber that you crank and crank and crank, and gradually the corner of the car rises. The shop manual doesn't mention that adjusting the front suspension is possible and I've never heard it anywhere. I only found out that's how it works by buying a deep socket to fit into the recess and trying it, after noticing that the nuts were greased, which is unusual. The one on the other side takes a different size socket wrench... so the left one was apparently replaced after the accident (before I got the car), by a different type... and evidently never adjusted afterwards. The left side still sits an inch lower than the right, but I turned it a long way I don't know how far to dare to go. The main objective, suspension!, is accomplished and the car rides much nicer.

New Brake Pads

I also bought new front brake pads on the 11th. I was getting some increasingly nasty grinding sounds lately when I braked hard - and there's no regenerative braking or any other way to stop the car if the brakes don't work, other than the hand brake. The brake pads were indeed worn right down,

with metal rubbing on the disk in one spot.
I had trouble getting the seized tires off. Just as I finished the whole job, a mechanic happened to walk by and said "That's easy! Just loosen the wheel nuts a bit, get in and turn the steering wheel back and forth. They'll pop right off." Ahrg!
I figured the rear brakes doubtless needed doing as well, and that won't work for them. I loosened the nuts a bit and drove back and forth a bit, punching the pedal in low gear and reverse. A wheel came off fine, but the rear brake shoes were almost like new. Too bad I had already bought new ones. It'll be a long time before I need them.

Windshield Defogger?

Quite a while back I got a small heater that plugs into the cigarette lighter. The heater installed under the dash by the original converters of the car evidently had almost immediately blown its internal fuse and wasn't very accessible. Naturally I want to replace this with a Peltier module heat pump rather than spend time on a heater that uses up a lot of power. For a quick means of defogging the windshield now that fall is here, I decided to mount the little heater on the dash and aim it at the windshield. (Aim is adjustable.) Unfortunately the cigarette lighter doesn't seem to work. Sigh! I threw a 12v NiMH tray battery with a cigarette lighter socket soldered to it into the car. Then I decided not to bother mounting the heater, either, and just have it handheld. It works. Hopefully need for it will be rare.
A 120 volt heater, eg 300-400 watts, placed in the car and turned on to warm the car up and (hopefully) defog prior to a trip while still plugged in/charging should do the bulk of the work.

Mazda Project Eats Time

The "Derelectric" RX7 is getting to be a pretty decent car now (except for the still non-functional heater-defogger), but I consider that if all the time I've spent on it, or even a good portion of it, had been spent on the ultra-efficient variable torque converter transmission, I'd probably have it and the Chevy Sprint running by now. On the other hand, I've been driving on electricity, and I've learned a lot of useful EV details.

Electricity (Energy) Production

Vertical Axis Wind Turbine

It looked like I had most of the parts for a wind turbine already. Later in the month clouds brought solar collection to low values and I couldn't charge the electric Mazda from it. I felt that between solar, wind, and a woodstove thermoelectric generator, I might attain some minimal level of electrical output most of the time. Of course, power by magnets or some other "free energy" device would be a better answer, but wind power seemed immediately attainable.
The rotor needs to be mounted on something solid so it won't blow away. I decided that since the logical place for the unit was at the peak of the roof of the house, the roof and the rafters would also constitute the mounting stand. The bearings and the generator would be in the attic and nothing need protrude through the roof except a hole for the 1" shaft.

The vanes roughly in position (I may fill those vent holes)
I had 4" PVC pipes about 2' long left over from the "super battery stick", a design which proved inadvisable. On about the 13th I split them in half. Then I put them in the oven (2 at a time - one fit on each rack) at 250°F for a few minutes to soften them (to floppyness). I pulled them out and used a weight to flatten one side and butted the other side against a 4"x4" board to keep it from sagging. The shape attained was a "J" shape, which apparently is something like optimum vane shape. Many people just use half circles from whatever tubes they use. The shapes were a little rough and varied, but all this only took a little over an hour one morning. If I did a proper forming jig, perhaps shaped out of wood, they could be fairly uniform and it would go even faster. If I could figure out how to make the rest of the job so quick and easy, VAWT s might be a pretty simple thing to produce for

sale.

As I see it, the round outside sluffs off wind on the side of the rotor heading into the wind, the shape generates lift like a wing (in the correct direction) in the windward area, and the inside of the "J" catches wind on the side pushing away from the wind. The downwind side probably doesn't do much of note. Thus from a little before the front to almost the rear, thrust is in the positive direction, without very much counterthrust from the vanes on the other side.

One might make most efficient use of the wind with vanes that swivel to always present their optimum face to the wind. But a slightly bigger turbine with fixed vanes can give the same power output with less complexity.

My plan was to glue a bunch of PVC pipes together and to the PVC vanes to form the entire rotor assembly. On the 15th I got the idea to run bands/rings, perhaps of PVC, around the outside of the vanes, too. This would help make it all more solid (the PVC pipes have considerable flex to them), and ensure nothing could fly off by centrifugal force. At least, not unless the force was strong enough to rip the plastic itself. If that happens, at least light plastic parts should be less hazardous than metal or wood.

But I do have plans to prevent over-revving. First, the generator load will go up with RPM. If the wind gets too high, I can use the excess to heat water or air. That will probably be sufficient. If not, I have ideas for air-brake vanes that are retracted by gravity but pop open centrifugally if the unit is spinning too fast. This is somewhat similar to the way tilted axis tail vanes on propeller type windplants turn the unit sideways in higher winds.

Shaping the vanes after heating them in the oven at ~250°F - wooden brace, steel weight.

But before I got very far making this, I discovered a known and powerful - but never considered - 24 hours a day, weatherproof, source of free radiant energy, and immersed myself in study.

Capturing Radio Signals & Powerline Fields

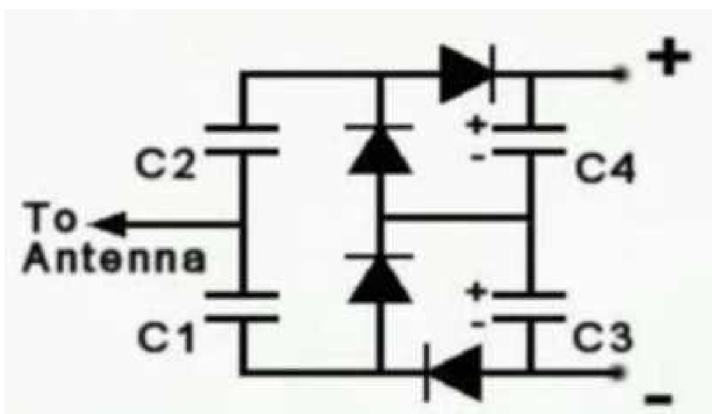
I started an interesting exploration of ways to turn invisible energies into electricity this month, after reading a message dated February 2003 that contained this digression from a topic of oil and war to come in Iraq:

"Long ago, the planet could have moved towards the use of a 'friendlier' fuel for your ever-increasing energy requirements. We greeted the wise use of hydropower with excitement. The safe and prudent use of water, and its conversion to clean, useable gasses was explored ages ago, and the discovery of space energy that constantly 'rains down' onto our planetary surface is also not new, and of the greatest potential and the cleanest available source when selectively applied by individuals and small groups.

"The 'almost costless' electricity produced can fuel many a range of appliances. In the end, the most useful application will be in the desalination of seawater and it will make your fertile deserts bloom without the pollution that is slowly making the environment uninhabitable." -- ABC-22

Since "space energy", if it existed, sounded promising, I started searching on that term and found an interesting site with what seems to be a novel method of generating electricity. For nearly a century Nicola Tesla's means for capturing energy "from thin air" has been suppressed and all but forgotten. The site claimed to reveal "Tesla's secret". There's a book for sale, and also a circuit shown on the web site.

The "hojo motor", a diode bridge circuit, plainly couldn't work Tesla's way: an 'antenna' is used rather than a 'plate' or a 'hollow copper hemisphere', and the antenna input is coupled through two capacitors. AC current would flow through capacitors C1 and C2 and be routed by the diodes to make DC, filtered by C3 and C4. The video link shows the circuit, with an unknown antenna, charging up a cell phone. This is so simple that if it makes enough electricity to be useful you wonder why it hasn't been thought of and used again and again.



A simple diode bridge circuit for a radio wave powered electricity generator.

Now, how close was that video done to a radio transmitter? We know that there are radio signals constantly traveling through the air. If you hold up a light bulb - fluorescent or sometimes even incandescent - near a transmitting antenna, it will light up, usually rather dimly, to varying degrees depending on the signal strength. No connections. I've seen this myself when I worked in radio in the late 1970s. Low to medium frequency radio signals seemed best, IIRC. (And I often hear what appears to be morse code and other LF data signals in my head when it's quiet, without any radio equipment beyond my ears - and perhaps fillings in my teeth acting as diodes.)

All very well if you live right next to a radio transmitter antenna?... But light bulbs aren't even made to pick up radio energy. Their "antennas" are laughable. (or did the person holding the bulb have to hold a bulb terminal? I can't remember.) How far away could they work if they had good antennas to pick up the transmissions?

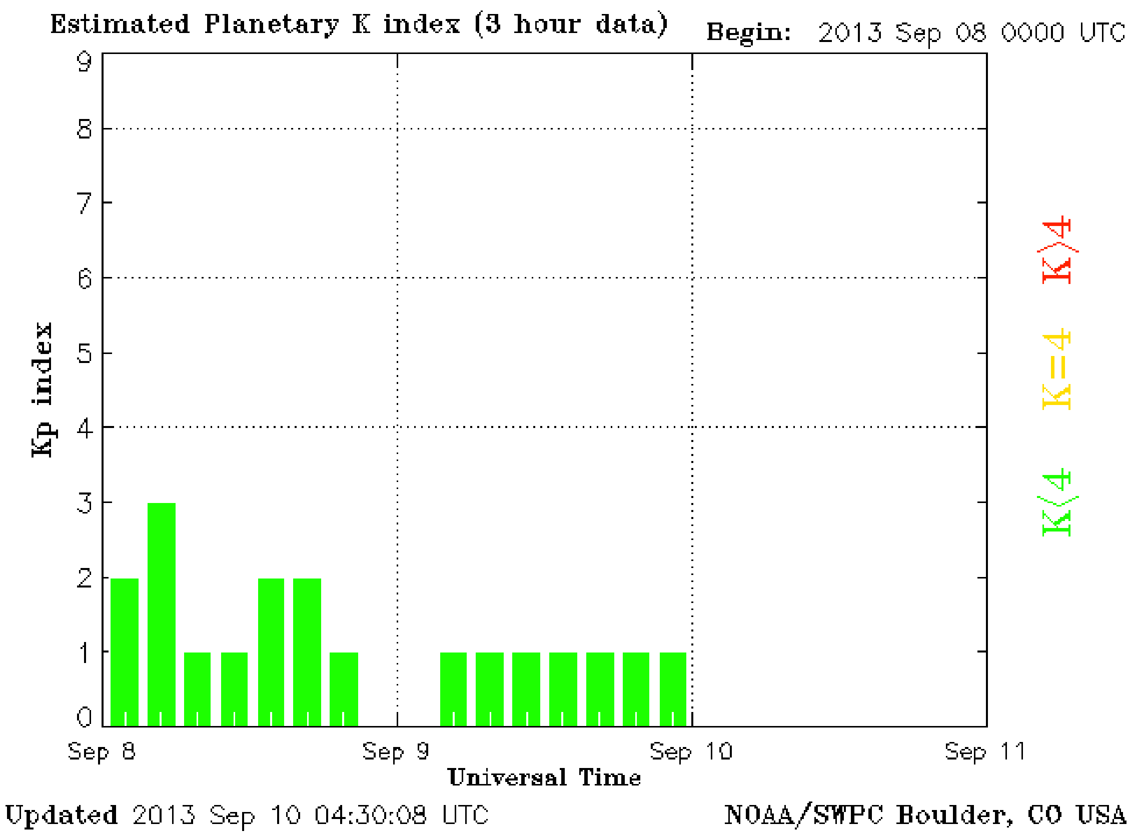
There are natural radio waves as well as man-made, mostly at very low frequencies. Perhaps most of us simply haven't suspected that they may contain *useful* amounts of energy. I looked this up on line. From the graphs I saw *nano*teslas of field strength, and *nano*watts per square meter of energy. This isn't very auspicious for getting great gobs of power, but perhaps it was worth trying out. Since the anticipated frequencies are very low, one suspects the longer the antenna the better. Perhaps

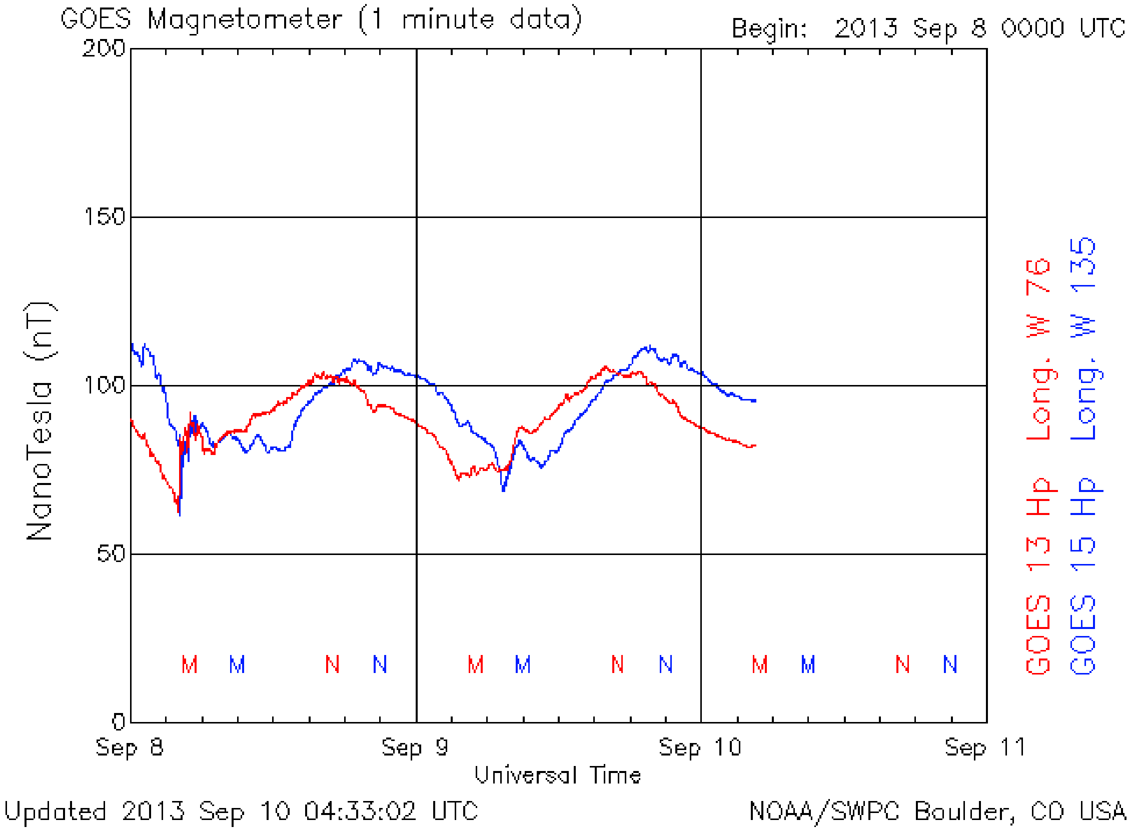
some tuned distance from the ground would be ideal.
Here's some info I found at a web site about natural radio signals:

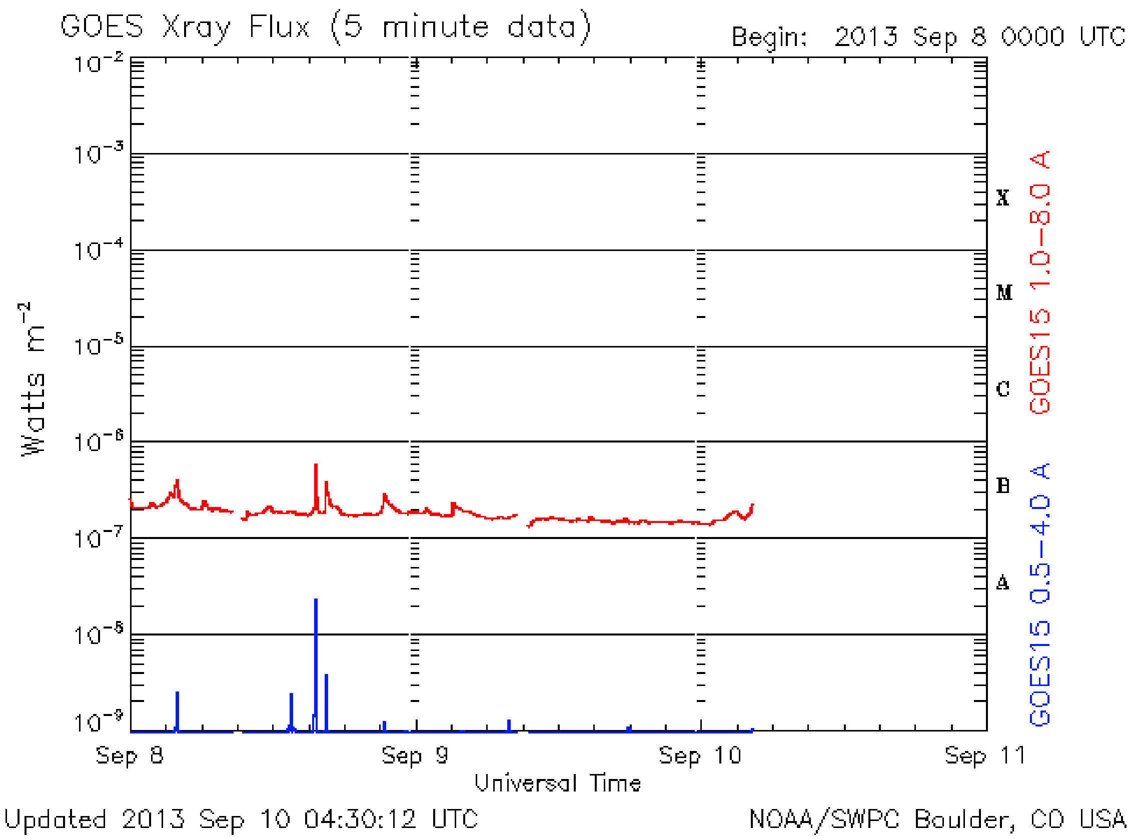
Natural Radio Lab [a web site]

Natural Radio is the VLF radio emissions that originate terrestrially from lightning and within the earth's magnetosphere through interaction with the Sun. These radio signals, sferics, tweeks, whistlers, chorus and others, occur within the range of human hearing, and can be heard with simple receivers as described on this site.
Natural Radio Lab also looks at Space Weather and the related solar activity that influences it such as sunspots, solar flares and Coronal Mass Ejections.
Please explore this site. I hope you go beyond reading what's here and actually go out and take the opportunity to hear whistlers or the enchanting sounds of the dawn chorus.

Mark Karney, N9JWF
Webmaster







I found the "Tesla's secret" website with the diode circuit info here:
http://www.magnetmotorz.net/hojo-motor
Soon I discovered an identical website:
http://www.energybytesla.com/

Then I found what may be the real source of the circuit, invented this year in April by Dennis Siegel, although neither the article nor Siegel's own web pages describe the circuit:
http://www.naturalnews.com/039814_radio_waves_batteries_charging_device.html
http://dennissiegel.de/electromagnetic-harvester/
I noticed that Siegel's site shows him next to power stations and various electrical things... so he seems to be mostly harvesting 50 or 60 Hz power line energy - to charge small batteries. That's not exactly the sort of abundant 'green energy' or 'radio waves' I was thinking of, tho it's not limited to harvesting from power lines.

Given that the name of the book is "Energy by Tesla", the first of the identical websites was probably copied from the second, where I found it looking for magnet motor designs. Now... what has the 47$ book got that the circuit on the web page doesn't... if anything? Does it expand on what the nuenergy.org site (below) has?

The question is, what frequency should the antenna and capacitive components be tuned for... or is tuning something to be considered? Capturing 60Hz power fields would imply a long antenna (or one next to a power wire) and very large capacitors. I have some 2.2uF non-polar capacitors for C1 and C2 - non-polar doesn't get much larger than that. The site mentions germanium diodes, which are rare these days but have the lowest forward voltage drop... best to have if the voltages expected are low. (not to be confused with geranium diodes, which have big red flowers.)

I decided to try out the circuit. If that yielded interesting results, I might order the book they offer and see if it's really practical to build something to generate more useful amounts of energy. (This was before discovering the CMBR stuff, below.)
I talked to ham radio buff Ian Soutar. He said such devices used to work better when there were higher output radio stations around. Evidently some used to be up to 250KW. I remember 50KW as being the maximum allowed. Now apparently it's something like 5KW.
Ian said that farmers living under high voltage power lines would make special transformers to harvest electricity from the magnetic fields, and power their whole barn (eg, lights and milking equipment) with them. This is certainly more than just powering a cell phone charger! Finally a specially equipped helicopter flew over all the power lines searching for magnetic field anomalies at barns, and all the farmers who had this equipment were fined for stealing power, even tho they had made no physical connections to the power lines.
He also said calculations for DC ionic energy showed absurdly low powers for very large investments. However, this was probably for building solid plate structures sticking up from the ground, rather than for vast fields of coarse mesh chicken wire hung from high altitude cables strung between hills or skyscrapers. (Maybe even up where lightning originates.) The reason coarse mesh chicken wire should work as well as solid plate is that electron deficient charged ions will veer to strike the electron rich ground (wires) from anywhere nearby.

This effect is strikingly illustrated on Saturn's moon Iapetus. Just 1440Km diameter, Iapetus orbits rather distant to Saturn, so it (like Jupiter's furthest moon Callisto (~4800-4840Km), which is about the same size as Mercury) hasn't been tidally churned to sink the good soil into the interior and leave glare ice on the surface (like, eg, Europa, Dione, Rhea...). Saturn's magnetic field drags ionized particles with it, creating a deadly ionizing radiation that strikes the rear ('East') hemisphere of all its moons from behind. Iapetus, with no sort of atmosphere or magnetic field, has no protection from this. However, the charged ions unerringly veer like lightning to strike high ground, leaving deeper crater floors and crevasses free of radiation.

Ion irradiated rear face of Iapetus. The edge of the dark, radiation free front face is seen at the right.
The dark vegetation can only grow in radiation free areas: deep crater floors, crevasses, near steep walls and under ice extrusions.
(Also it's evidently too cold toward the poles and on polar facing slopes
- this vegetation would be a migrant from Ganymede or Callisto, much closer to the sun.)

It seems remarkable that vegetation of any sort might grow on cold, airless worlds, but it's the only logical conclusion that appears to explain various science findings about the dark surfaces such as the spectrographic data (eg, "polycyclic aromatic hydrocarbons" - definitely stuff of life), the diurnal temperature profile indicating a "very fluffy" surface 'that's penetrated by sunlight', a landscape which is 'rapidly resurfaced after meteor strikes', plus the striking correspondence of the dark surfaces to the seemingly non-irradiated areas in the images.

But I digress... and then digress from the digression.

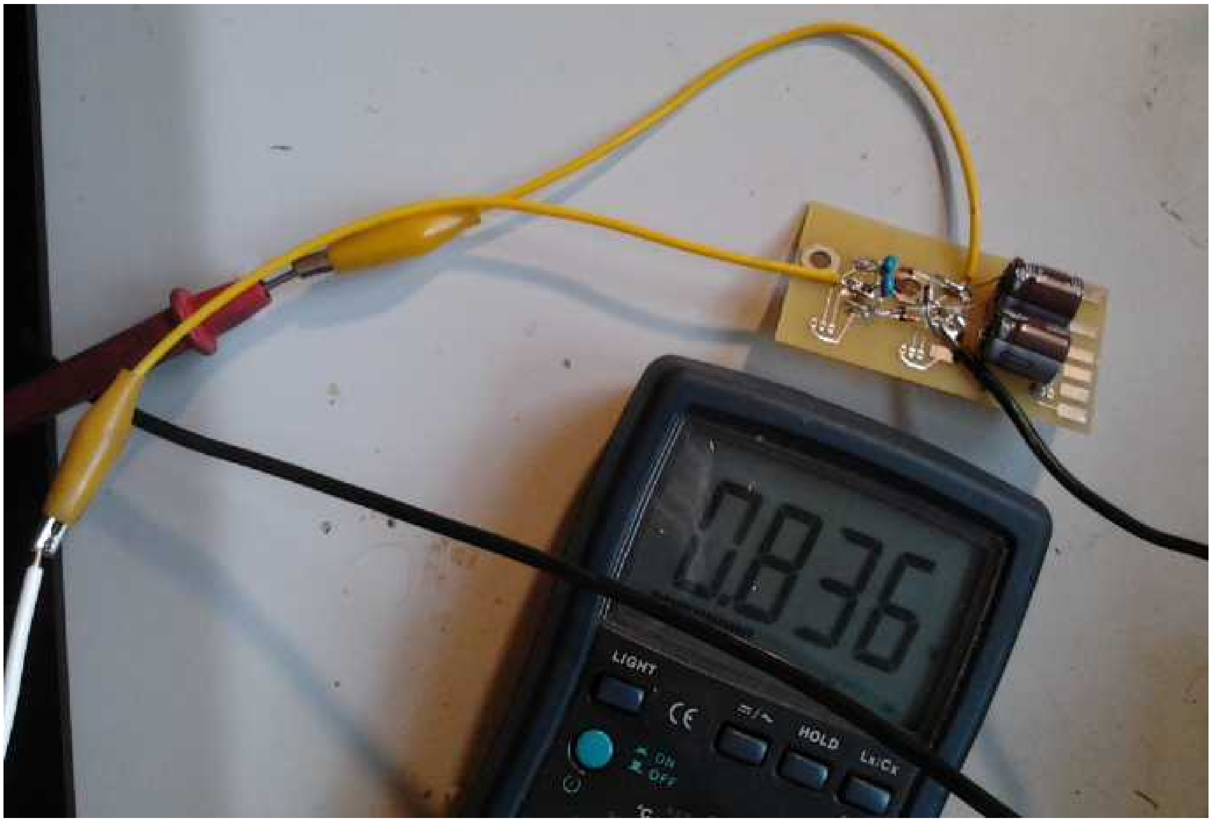
Radio/powerline field harvesting circuit: Slim Pickings

On the 15th or 16th I put together the circuit with common 1N4148 silicon small signal diodes, 2.2uF non-polar capacitors on the input and 100uF capacitors on the output. I added a 15 volt zener diode in case the output voltage actually got that high. I soldered on 3 aligator clip leeds for "antenna", "+" and "-" connections.

I clipped on a 10' wire for an antenna, grounded the board at my lab power supply, and clipped a meter to the output. It read 1/2 a volt and was very gradually rising. When it hit a volt after a couple of minutes I left the room. When I came back it was 1.5 volts... and falling. Whatever had been imparting energy to it seemed to have shut off. It fell to about 1 volt and stayed.

Then I took it over to Ian Soutar's 40 meter dipole antenna. Ian said his back yard was very quiet radio interference wise, which made it a good place to make ham radio calls from. Results at best showed similar voltage increases with time, and other things we tried were worse. In a park away from power lines with a long extension cord for an antenna, not much seemed to happen at all. (But I'm not sure I got a good ground.) Ian did say that it definitely needed to have germanium diodes with their low .2-.3v forward drop instead of silicon at .6-.7v, since signal levels were bound to be very low.

I went to buy some and was told that the forward voltage drop wasn't so low. I bought some



1N5817 schottky diodes instead, which are about .35v forward drop at low currents. It didn't work worth beans with those. It got up to about 2-1/2mV instead of 1.5 volts. My theory is that the 1N4148 s, being fast, small signal diodes, have lower leakage so they don't bleed off the accumulating voltage. Even the tiny voltage on the Schottkys dropped off quickly when the antenna was disconnected, indicating leakage current.

It didn't seem at all promising, but not to leave any stones unturned I went back the next day (17th) and got the 1N34A germanium diodes. (Seeing just two digits instead of four after the "1N" ("1" semiconductor junction = diode) reminds one that these harken back to the very first germanium semiconductors of the 1950s. Silicon came later.)

On the 20th I finally soldered them on. The voltage proceeded to drift *negative* to tens of millivolts. It didn't seem to care whether the antenna was connected. Ugh! I started to wonder if even the original results really meant anything.

To find out I unsoldered the 1N37A s and put the 1N4148 s back on. Sure enough, when the antenna was connected the voltage began rising steadily in the proper direction, millivolt by millivolt, to over 1/2 a volt. With the antenna disconnected the voltage started dropping faster than it had been rising. The original 1N4148 s that I chose because I had them at the time, were the best of any I tried, and indeed the only ones that worked at all. But it looked like it would take a coon's age just to charge a cellphone, if I could get it to work at all. It might work with the antenna right next to something drawing a lot of AC power.

As a last experiment I took off the 100uF polarized capacitors and replaced them with two more of the low leakage ceramic 2.2uF ones. I also removed the 15v zener diode since the voltage never got very high. The voltages changed much more rapidly with the smaller capacitance and attained higher values with the low leakage. It soon passed a volt and went up to about 1.2v. Setting the meter to milliamps showed .000mA short circuit current - not even a microamp. Ten in series with ten antennas would have supplied 12 volts at some infinitesimal current - or maybe 6 volts at a higher infinitesimal current.

In the meantime I had started finding other versions of what Tesla had done on 'nuenergy.org' website, and then equating vague undefined terms like "space energy" and "zero point energy" with the "cosmic microwave background radiation" ("CMBR") known to astronomy. nuenergy.org got me started thinking about the Tesla and Markovitch energy converters. I abandoned the apparently fickle project of harvesting powerline and radio fields with an untuned circuit to obtain minute amounts of energy. Seeing the voltages rise on the meter illustrates capture of invisible energy out of the air -- but to get real energy harvesting, it would be better to tap the wavelength where the bulk of the natural radiant energy of the universe really is, with a circuit tuned to take real advantage of it!

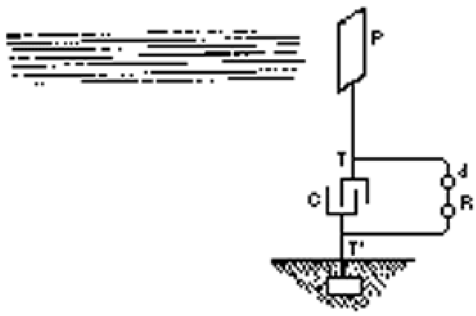
Cosmic Microwave Background Energy ("CMBR" or "CMB") to Electricity

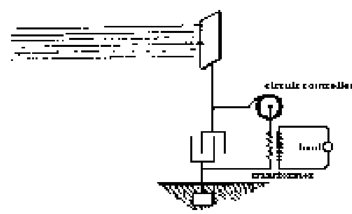
Harvester/Collector/Converter

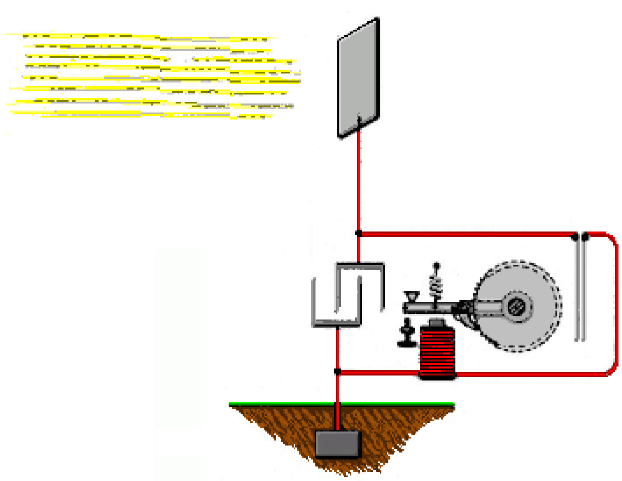
There seemed to be a large discrepancy between the circuit and what Tesla was doing. According to the site, Tesla's thesis was that the Earth has a negative charge compared to the ions coming from the sun, or from atmospheric atoms ionized by the sun. This DC charge causes lightning. What seems less clear is whether this force can be harnessed with nothing more than a plate on a tall pole to charge with this ionic energy. Tesla said the current is 'feeble', but that the voltage builds up and up until it arcs across the capacitor plates.

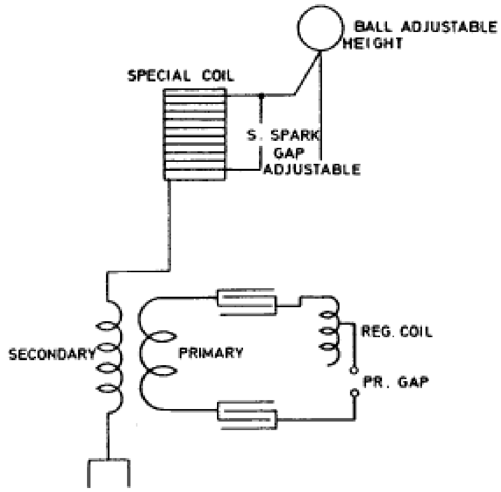
In his circuits he mentions a coil and an oscillator. This didn't make much sense: one doesn't usually use coils with DC circuits. It's commonly said that Tesla's power generator was 'very successful', but if current is 'feeble' and it takes considerable time to build up the voltage, that's not an indication he was getting very much power. Evidently many people since Tesla have done some calculations and decided that harvesting atmospheric ion energy wouldn't be worthwhile: building something large enough to harvest useful energy would cost far more than any returns obtained.

But would it need a solid structure? A very large wire mesh strung on a cable between two mountains might provide worthwhile DC energy. For a relatively low cost, that would put a very large receiving "plate" up far away from the ground, where the charge is greater. It would probably be beyond the scope of any sort of home project, but perhaps an experiment using a wire mesh hanging from a skiing chair lift cable in the off season might give an indication of the potential of the idea.









Tesla's(?) idea: capture energy from the high voltage positive charge in the air.
But that idea doesn't explain some of the circuits.

Tesla said (among other things):

From the electric Potential that exists between the elevated plate (plus) and the ground (minus), energy builds up in the capacitor, and, after "a suitable time interval," the accumulated energy will "manifest itself in a powerful discharge" that can do work. The capacitor, says Tesla, should be "of considerable electrostatic capacity," and its dielectric made of "the best quality mica, for it has to withstand potentials that could rupture a weaker dielectric."

"The sun, as well as other sources of ***radiant energy*** throw off minute particles of matter positively electrified, which, impinging upon the upper plate, communicate continuously an electrical charge to the same. The opposite terminal of the condenser being connected to ground, which may be considered as a vast reservoir of negative electricity, a ***feeble current flows continuously*** into the condenser and inasmuch as the particles are …charged to a very high potential, this charging of the condenser may continue, as I have actually observed, almost indefinitely, even to the point of rupturing the dielectric."
- Nikola Tesla

But this didn't explain what the coils were for. Another web site had quite different ideas of what Tesla was doing:
http://www.nuenergy.org/space-energy-receiver/
"
The device in question is one of a number of energy transducers that converts ***extremely high frequency*** energy to a form comparable to alternating or direct current electricity. The process involves in all cases, the utilizing of the instrument as a specially designed resonating cavity. This cavity can be composed of either a number of crystals, a series of coils, or a combination of the above. To understand how the unit operates, it is first necessary to briefly describe the nature of this energy source.

Research and experimentation have established that this energy is one that pervades the known universe and is constantly flowing through the Earth itself. It has been found to be quite dense, with enough power to light an American city of around 50,000 persons for a year. Because of its origins and immense power potential, this energy has been called "vacuum," "cosmic," "radiant," or "zero-point" energy. Dr. Nikola Tesla, the discoverer of the electric age, may have used this energy to create his most fantastic invention-the "Magnifying Transmitter."
"

Sometime early on, it occurred to me that "space energy" and such names as those quoted above, and the "cosmic microwave background radiation" ("CMBR" or "CMB"), were probably - and soon I felt surely - the same thing. CMBR was doubtless the grain of truth behind all the vague, undefined terms.
In the paragraphs above are the clearest concepts of what is being tapped. The "research and experimentation" have apparently uncovered the strong EHF energy radiance, but remarkably, without identifying its wavelength or realizing that this is the same energy that's known as the CMBR to astronomy. Here we have Tesla and others converting not DC ions but this EHF "Space Energy" to some usable frequency of electrical power. This explained the use of coils and tuned circuits. But part of the confusion is probably owing to Tesla himself not knowing exactly what he was doing: science wasn't as advanced as today and it's said Tesla didn't even believe in the new idea of subatomic particles at that time - notwithstanding that he was working with them.

It was noted that the electrical currents flowed around the outside of the wire and not in the center, the "skin effect" consistent with very high frequency current. And it's noted that the frequency is so high that the energy only appears like 'normal' electricity in some respects, and unlike it in others. This sounds like an energy that needs to be 'stepped down' in frequency and form to turn it into something usable and essentially recognizable.

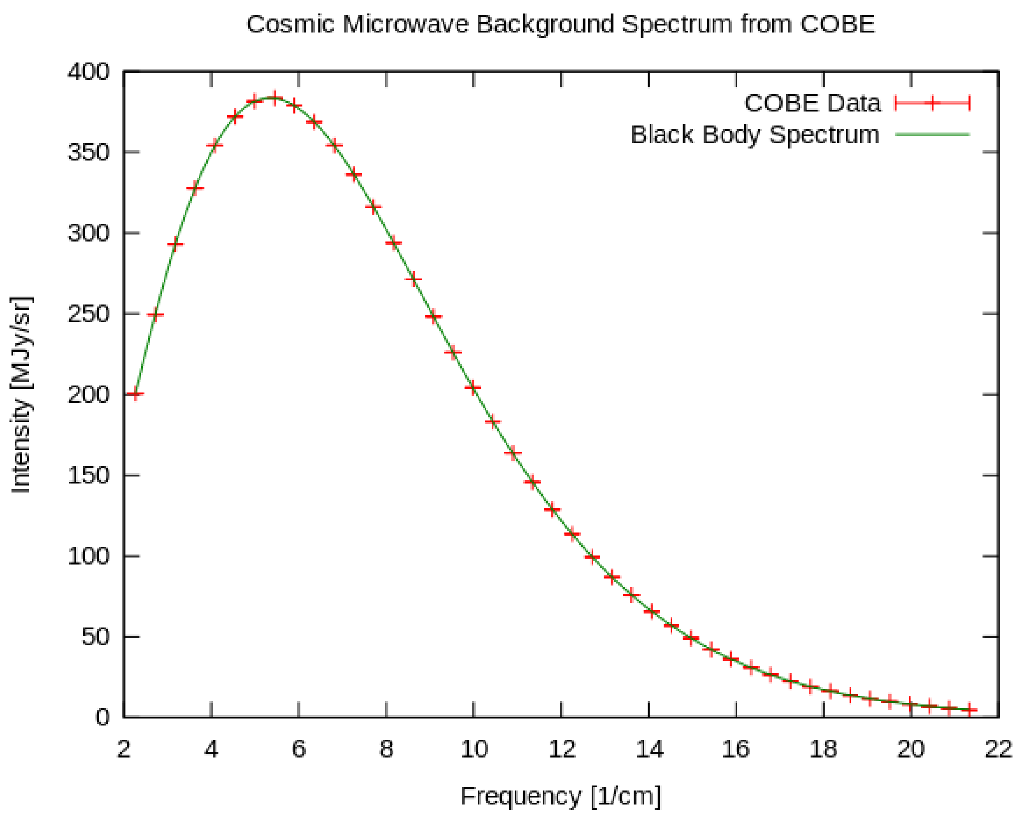
Power from a 'space energy collector' device by Markovitch in the 1970 s was reputed to have produced 180V and 3A. Presuming that's both at the same time, it's 560 watts. Later I heard of the 50KW machine of the 1930 s. This sort of power sounds like something more more able to generate the story of Tesla's success that's been passed down through the decades. A "resonating cavity" sounds a lot like a "waveguide" as in a klystron or magnetron tube for radar and microwave frequencies. It takes knowledge and expertise to design and to build the requisite circuits (as well as some luck if your understanding of what you're doing is vague), which explains why Tesla's work hasn't more often been duplicated. Nevertheless, the nuenergy.org site provides a description of what needs to be made. There are a couple of pictures. Perhaps together with the text they're sufficient.

Back to the CMBR... First, note that so-called "microwaves" are really "centiwaves". The ones used in radars and "microwave" ovens are several centimeters wavelength. Next, from Wikipedia article "Cosmic Microwave Background":

"The spectral radiance $dE_\nu/d\nu$ peaks at 160.2 GHz, in the microwave range of frequencies. (Alternatively if spectral radiance is defined as $dE_\lambda/d\lambda$ then the peak wavelength is 1.063 mm.)" [the zero is surely a mistake and it's 1.863 or 1.63mm.]

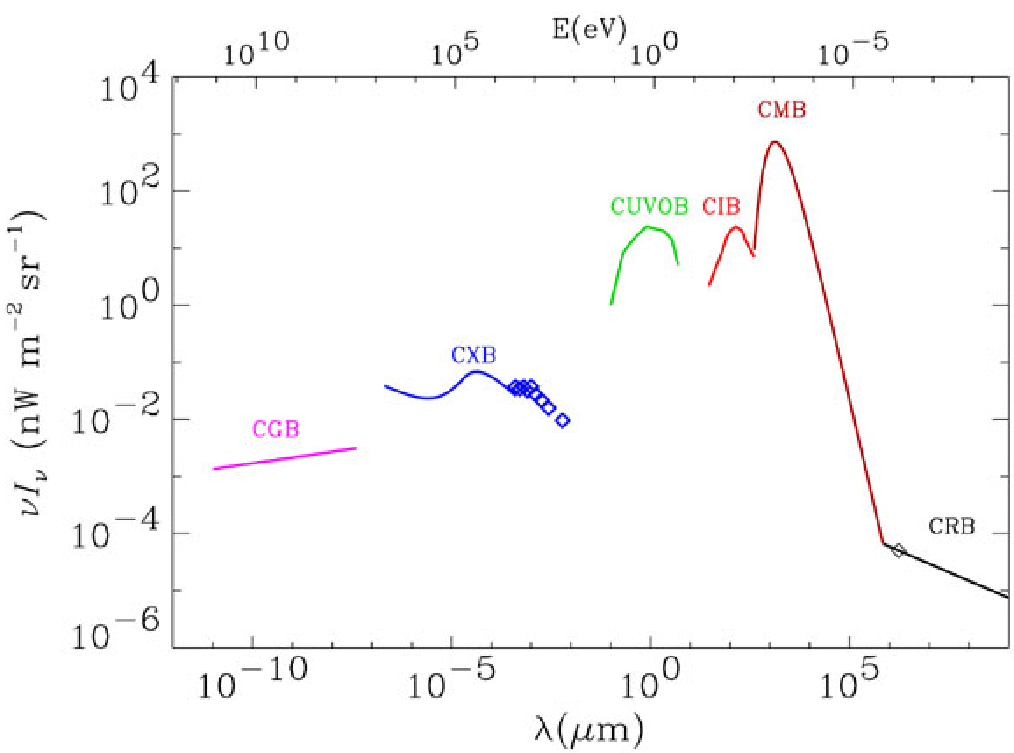
According to some definitions, that's above microwave frequencies - between them and the far infra-red. And, most interestingly for free energy: "**Most of the radiation energy in the universe is in the cosmic microwave background**."

Here we have apparently a very substantial energy that pervades the known universe.



CLASS	FREQUENCY	WAVELENGTH	ENERGY
γ	300 EHz	1 pm	1.24 MeV
HX	30 EHz	10 pm	124 keV
SX	3 EHz	100 pm	12.4 keV
	300 PHz	1 nm	1.24 keV
EUV	30 PHz	10 nm	124 eV
NUV	3 PHz	100 nm	12.4 eV
NIR	300 THz	1 μm	1.24 eV
MIR	30 THz	10 μm	124 meV
FIR	3 THz	100 μm	12.4 meV
EHF	300 GHz	1 mm	1.24 meV
SHF	30 GHz	1 cm	124 μeV
UHF	3 GHz	1 dm	12.4 μeV
VHF	300 MHz	1 m	1.24 μeV
HF	30 MHz	10 m	124 neV
MF	3 MHz	100 m	12.4 neV
LF	300 kHz	1 km	1.24 neV
VLF	30 kHz	10 km	124 peV
VF/ULF	3 kHz	100 km	12.4 peV
SLF	300 Hz	1 Mm	1.24 peV
ELF	30 Hz	10 Mm	124 feV
	3 Hz	100 Mm	12.4 feV

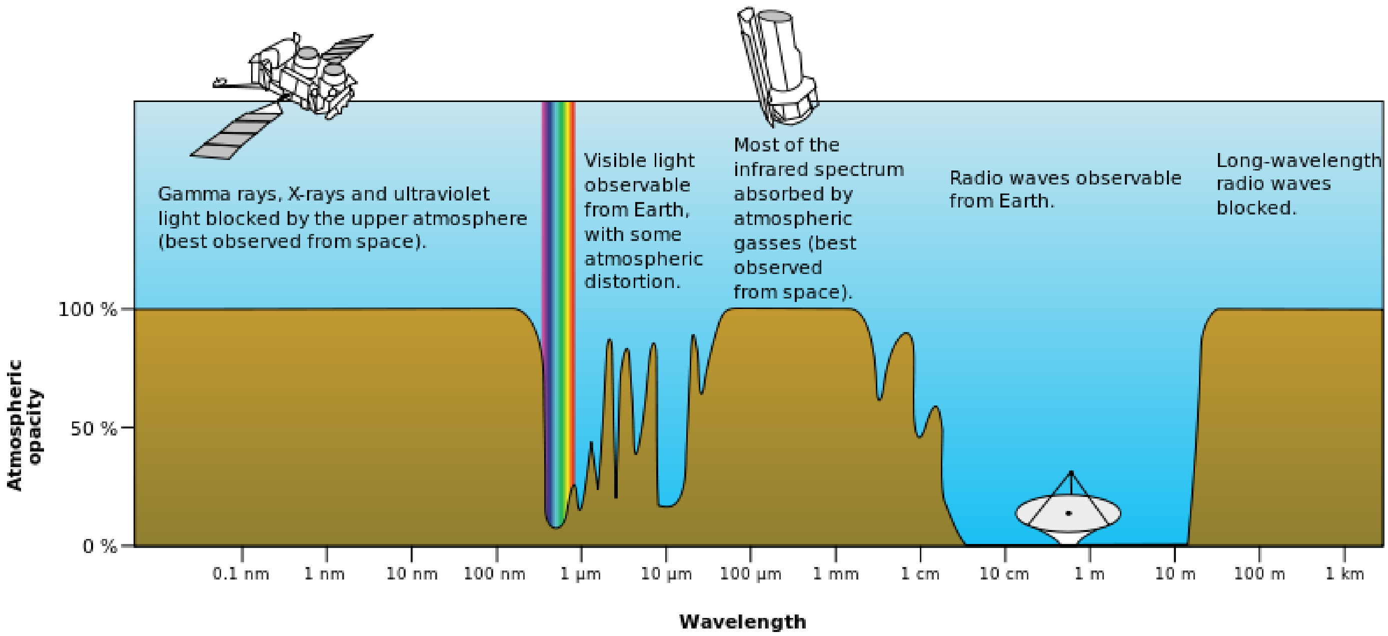
The graph shows the wavelength of maximum intensity as just under 1/5cm or 2mm. (1.863mm would probably agree with the 160GHz figure.)



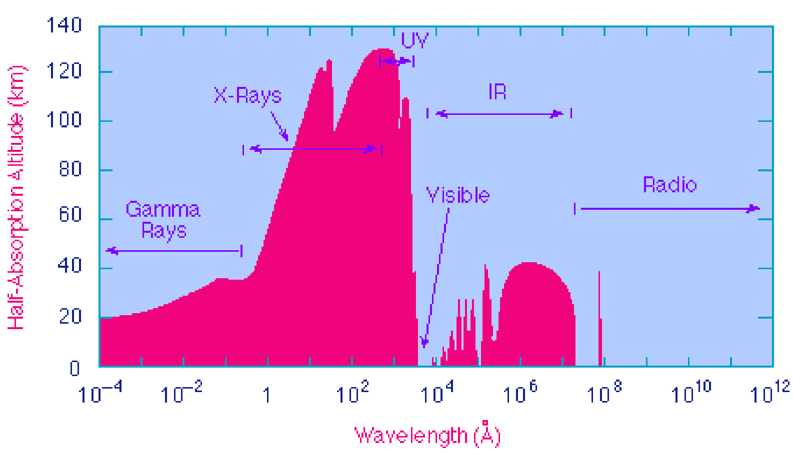
CMB appears to be much more powerful (50x?) than sunlight.
http://www.cv.nrao.edu/course/astr534/Introradastro.html

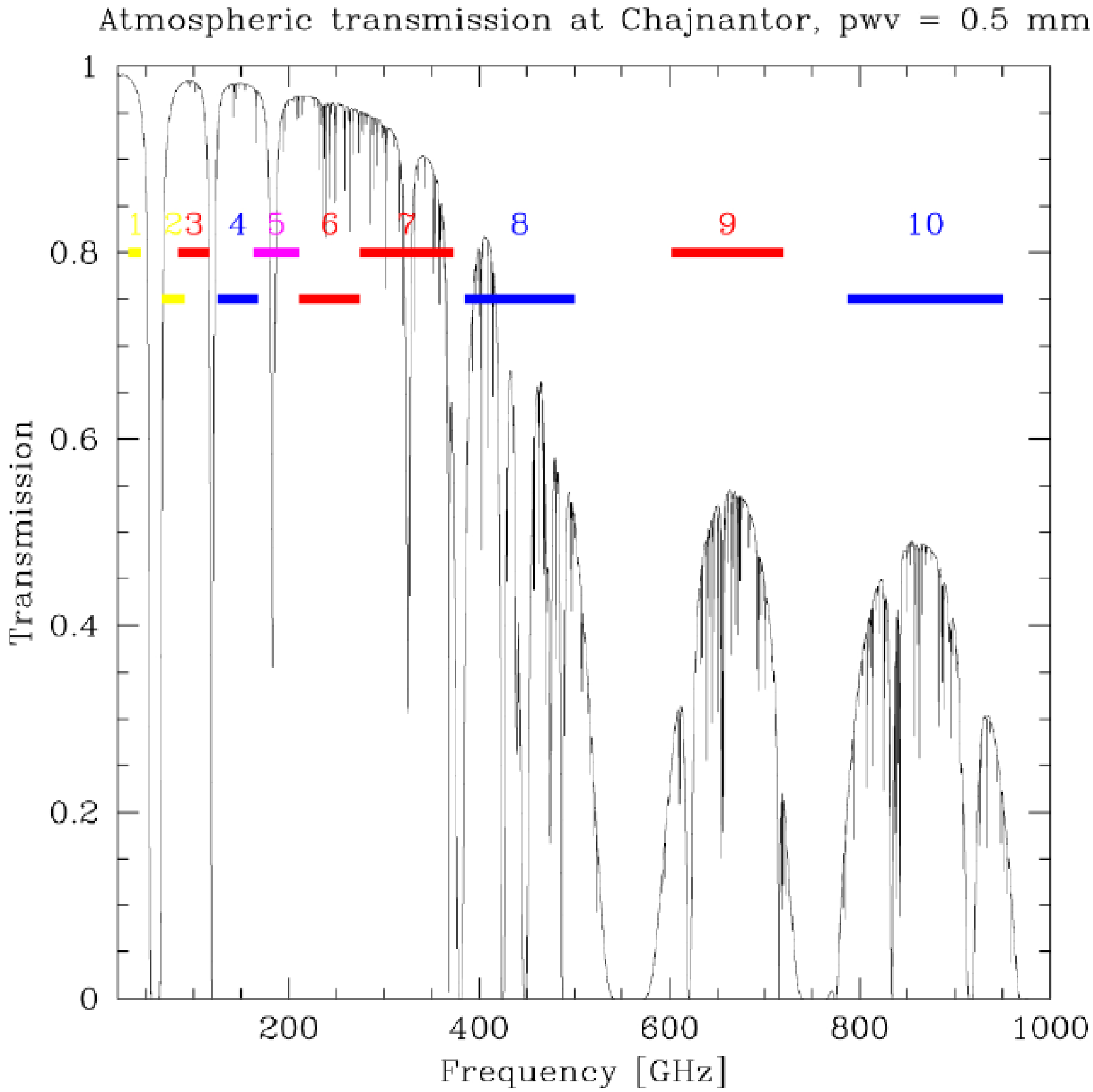
This broad spectrum view shows the CMBR (CMB) as having almost a couple of orders of magnitude more energy than any other frequency band. Unfortunately the term "sr" isn't explained and no meaning comes to mind as I write. Ignoring that, a microwatt per square meter at the peak doesn't *seem* like much, but there are claims of getting considerable power on the order of at least tens of

watts and even tens of kilowatts (Tesla, Markovitch). A tuned circuit amplifies signals manyfold, and the energy collected isn't necessarily limited to the size of the collector surface. (And what is "sr"?)



The atmospheric absorption of energy at various spectra seemed interesting. Radio wave energy is a wide band that can come straight in from space almost unaffected by the atmosphere. However, looking at the chart above it didn't appear to include the 1 to 5 mm energy area of the cosmic microwave background. That seemed to more or less rule out harvesting cosmic microwave radiation... which seemed puzzling if it had been done. (The caption did say it was a "rough plot", but it also claimed absorption "above 20GHz".) So I searched and found another graph from another source, below. The difference was night and day! This one showed atmospheric transparency in the critical area of high energy, from about 2mm to 8 or 9mm. (1 cm = 10^8 ångstroms.) Really it only indicates for certain that "less than half" the CMBR energy is blocked at sea level, so both graphs may be somewhat misleading. Even according to the first graph it's not entirely blocked. But going by the second one, at least over half of the CMBR energy reaches sea level, and with the steep sides, it seems more likely that the bulk of it gets through. This was later confirmed by a third, more detailed, chart, which shows practically all the energy at 160GHz reaching the ground, albeit at a high desert elevation.





http://www.cv.nrao.edu/course/astr534/Introradastro.html

So it seems that the microwave background energy does reach Earth's surface, and thus it should be possible to capture it with a working system tuned to somewhere between a 1.4 to 2.5 mm wavelength, and that this is 'most of the radiation energy in the universe'. It could be harvested anywhere, including in space to power spacecraft, replacing solar power and RTEGs. It would appear from more than one source that CMBR is the free energy 'big fish', known yet unknown for a century!

What's needed, then, is an assembly - parts of it can hardly be called a circuit - to capture this energy. The principles of working with wavelengths that are very short in comparison to the components (at least on centimeters scale) are reasonably well understood, and the striplines and resonant lines ideas will be noticed in common in the designs that follow. From Wikipedia ("Microwaves"):

"Open-wire and coaxial transmission lines used at lower frequencies are replaced by waveguides and stripline, and lumped-element tuned circuits are replaced by cavity resonators or resonant lines. In turn, at even higher frequencies, where the wavelength of the electromagnetic waves becomes small in comparison to the size of the structures used to process them, microwave techniques become inadequate, and the methods of optics are used."

As I read more and more stuff, there seemed to be some common principles emerging - similarities between devices, with toroids or rectangular frames having transverse 'control' wiring, close parallel wire loops, sharp excitation pulses with solid state drivers, and so on.

It seems that many people with dozens of designs have managed to tap the CMBR over the years -

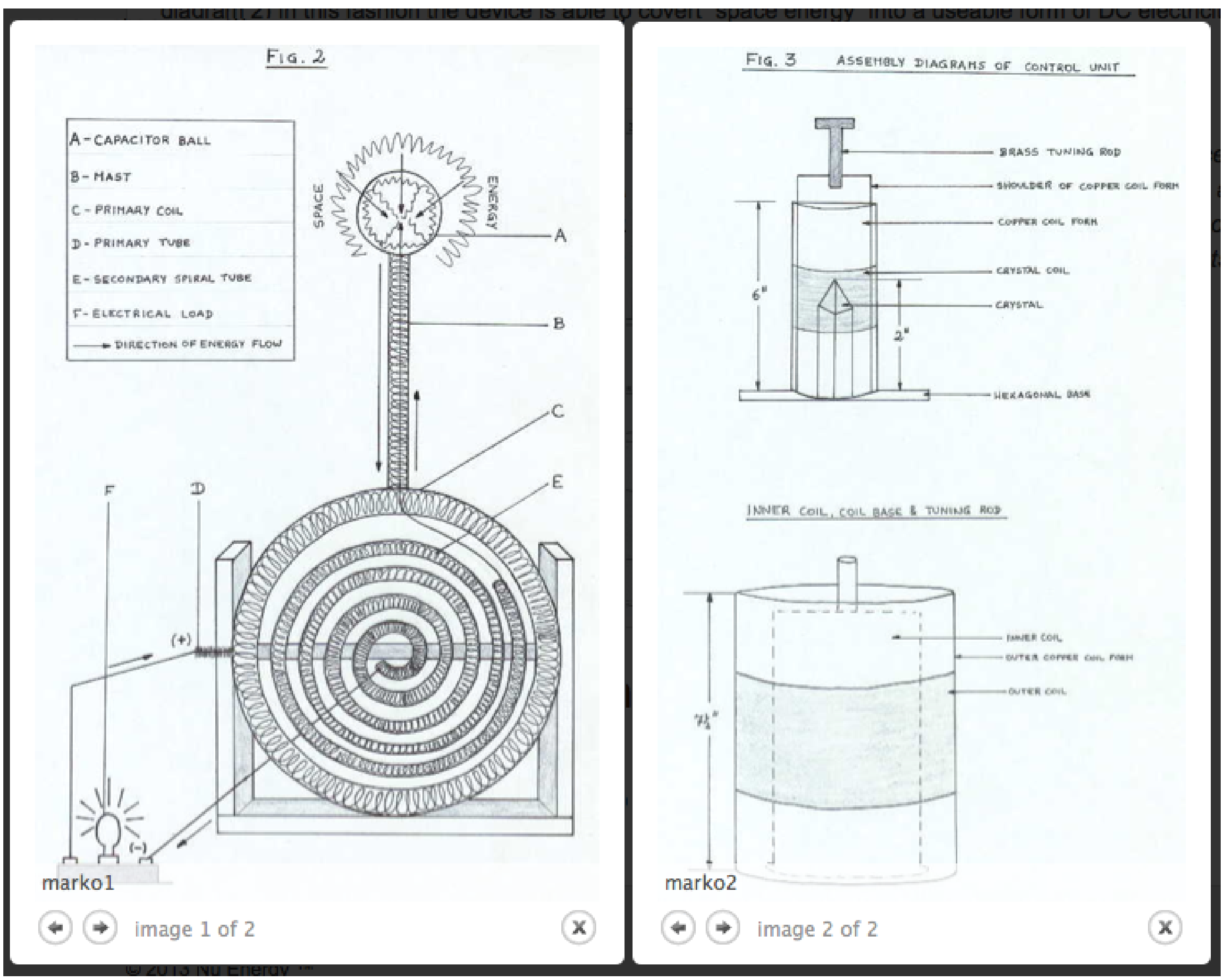
the invisible but 'brighest' radiance in the whole electromagnetic spectrum - without a clear understanding of what it was they were tapping.

The CMBR's 160 GHz is at the upper frequency limit for radio techniques, a little below where optical techniques become more effective.

What has happened in the century and more since Tesla first lit banks of light bulbs with power from the void? As a friend told it (from web info): "There was a man named T. Henry Moray back in the 30's or so who developed a "box" that could pull 50kW continuously out of "space". His device was witnessed by many scientists and engineers of his time, but he faced a lot of opposition and had his equipment and lab smashed etc. If I understand anything about it, the principle was some sort of resonant condition excited by a natural energy vibration in the ether." (His patent was apparently "lost" by the patent office.)

Again it seems like the typical bitter experience of someone who had the temerity to try and lift mankind out from the clutches of the gangster-parasites who (so far) control our society, and to try to help us get clear of the intake hose of their greedy 'money vacuum cleaner' of "pay per fillup" and "pay per month" energy that's causing wars and gradually ruining the environment. I've read of worse.

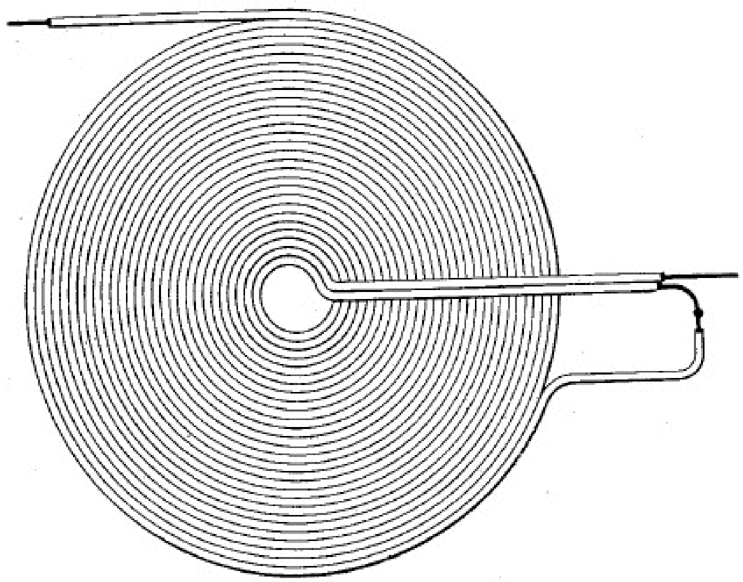
And again the "natural energy vibration in the ether" is doubtless explained as the CMBR. 50KW is the largest figure I've seen yet, and very promising to say the least. It would be plenty to power an electric car. I wonder how big the device was? Doubtless there's some figure for "[kilo]watts per square meter" of radiance actually available. If it's comparable to sunlight and 50 times as powerful, it would be 50 KW/sq.m since sunlight is very close to 1.



Performance of the Markovitch "Space Energy" harvester in the late 1970 s:

"According to reports the device is supposed to have worked, with maximum voltage of around 180V and 3 amps. Strangely both a DC and an AC component were found in the output. There were some pretty high powered witnesses to these experiments including scientists and technicians."

Unfortunately the 1970 s is a while ago now. It would be great to be able to find witnesses or Markovitch and learn more. Some key features appear to be a plate or globe perhaps 1/2 a meter or more in diameter and a gap to a needle point that the energy jumps across. Then some weird 'bifilar' coils maybe with some kind of crystals. That's pretty vague stuff to go on.



Tesla's "Bifilar Coil"
The signal travels from the outside to the center twice, with the second loop parallel to the first.
This was said to multiply the inductance manyfold.
(I note that the ***gap between the two wires*** is similar to the wavelength of the CMBR rays.)

Other 'Free Energy' Devices

My present theory is that at least two "hidden" energies are available for harvesting:
1. Nuclear (or perhaps ambient thermal) energy brought from the atomic scale to the mechanical scale via magnetism.
2. Cosmic Microwave Background Radiation.

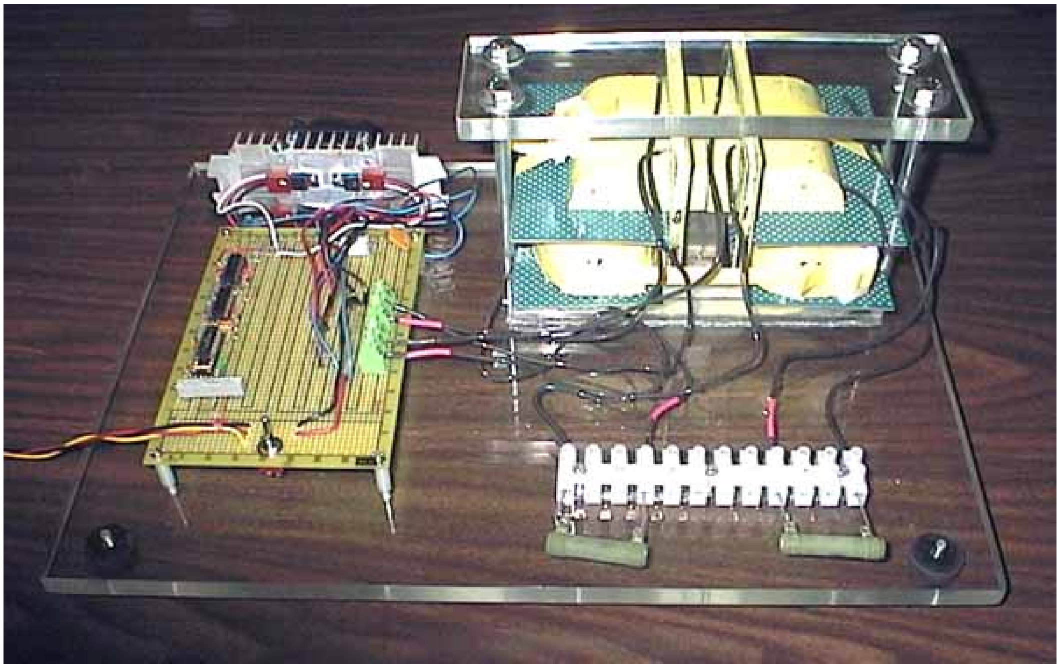
Cruising through web sites looking for more info, one can hardly avoid finding more novel ideas for harvesting "energy from the void" and magnetic energy. At first I ignored anything that didn't look like what Tesla had done, but I started finding some free energy 'pulsed transformers' that looked interesting, and which were also probably 'harvesting' BMBR.

Here's a "motionless electric generator" ("MEG") apparently patented about 2002 with a transformer that is supposed to resonate and have a "COP" of 5, producing 5 times as much energy as it consumes. http://jnaudin.free.fr/meg/meg.htm . It's supposed to be up to version "Mark 4" now. A mark 3 was made by another person, Naudin, showing that the design is replicable. But one suspects he got verbal instruction from Bearden beyond what's written in the patent. Now I've run across other units with similar themes. Again it would appear from undefined and unexplained terms like "Active Vacuum" that the makers, like Tesla and others, don't really know where the energy to make them work comes from.

The Motionless Electromagnetic Generator,

Extracting Energy from a Permanent Magnet with Energy-Replenishing from the Active Vacuum

from Thomas E. Bearden, Ph.D. James C. Hayes, Ph.D. James L. Kenny, Ph.D. Kenneth D. Moore, B.S. Stephen L. Patrick, B.S.



"MEG mk2" showing oscillator and coil driver components.

"..This one works beautifully and produces COP=5.0..." has said Tom Bearden

US Patent 6,362,718 : Motionless Electromagnetic Generator

(The link on the site to the US patent office generates an error. I've put in one that didn't.)

One wonders what has happened to these devices. It seems they've never been mentioned in the media, and it hasn't started replacing the power grid in over a decade of existence.

On reading more about this device, it would appear to be a modified way to tap the CMBR rather than a magnetic power source. A permanent magnet may seem like an odd feature, but the magnetron, a well known microwave tube, has one, so use of magnets is commonly associated with microwaves. At first it looked like it might be the easiest unit to construct, but on the website, cheniere.org, maker Bearden speaks of 'nanocrystalline core material' and says it won't work with an iron core. Turquoise Energy Newsletters of the past show that I had no real success trying to create such cores (although the ilmenite in sodium silicate coil coatings improved the efficiency of the Electric Hubcap motors, and may well have application here).

Funding, especially for advanced techniques probably needed to produce such cores, is evidently what's been holding up commercial production. Naturally, it's the corrupt that have nearly all the wealth, and they certainly wouldn't want to fund something that would let people make their own electricity freely.

Perhaps the iron powder cores I have for Electric Hubcap/Caik/Weel motors could have application? If not, the maker (micrometals.com) does have other core material choices. But not the sort of transformer double "C" core shapes shown.

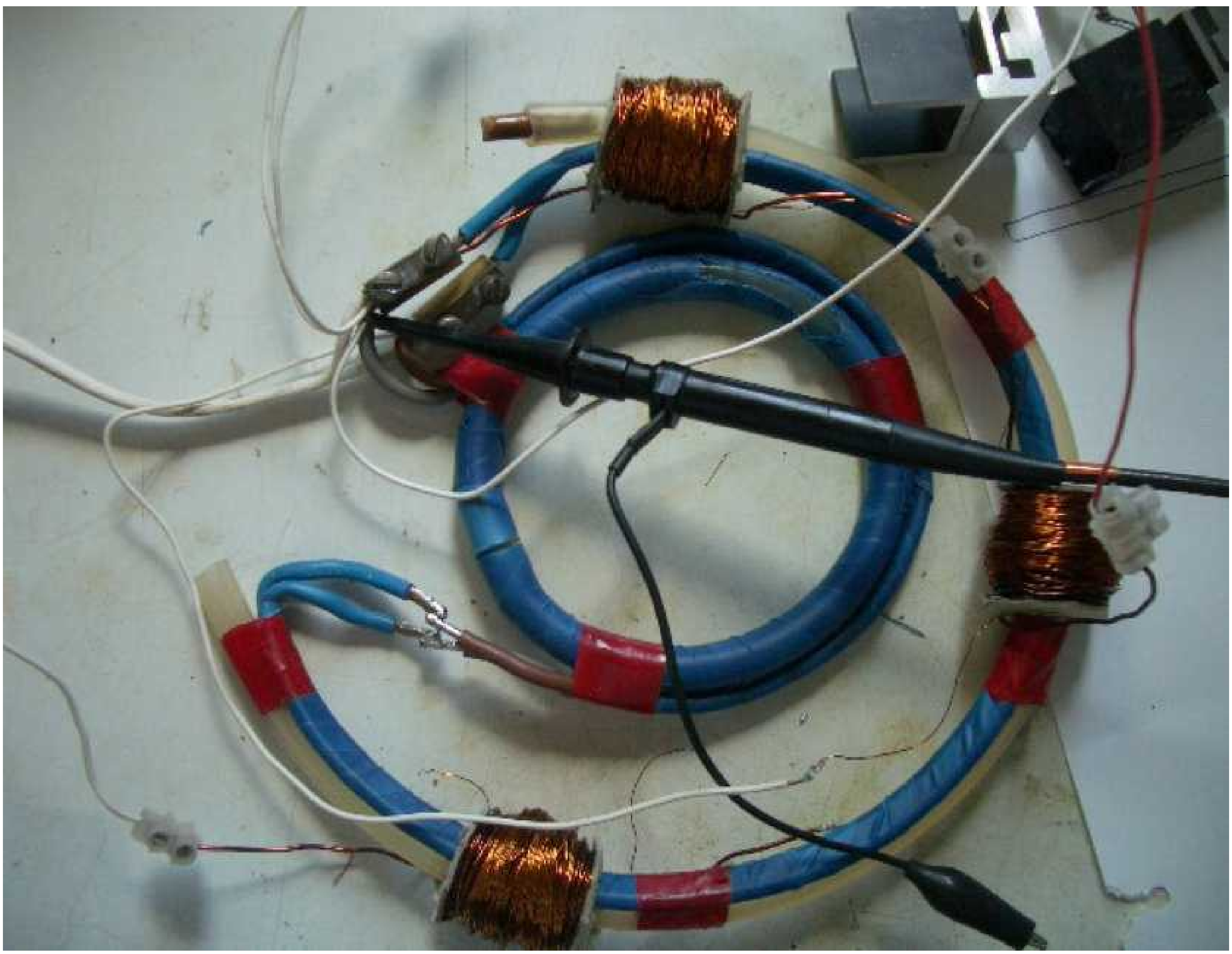
A Simpler Pulsed Transformer Design

In my web searches I had clicked on many links, each opening in a new window. A couple of days after investigating the above unit, I found a window on my screen, hidden behind others, with another 'pulsed transformer' energy design. This one looked easy to make, using air cores, and the construction details were shown in a PDF document. An irritatingly tiny photo of the device on the web site turned out to be in fact 1280 x 960 pixels if downloaded, big enough to see a lot of detail. URL:
http://freetesla.blogspot.ca/2011/08/successful-tpu-ecd-replication.html

The site was in fact showing someone's working replica of a 2007 design found in a PDF document at:
http://www.overunity.com/index.php?action=dlattach;topic=2383.0;attach=9524

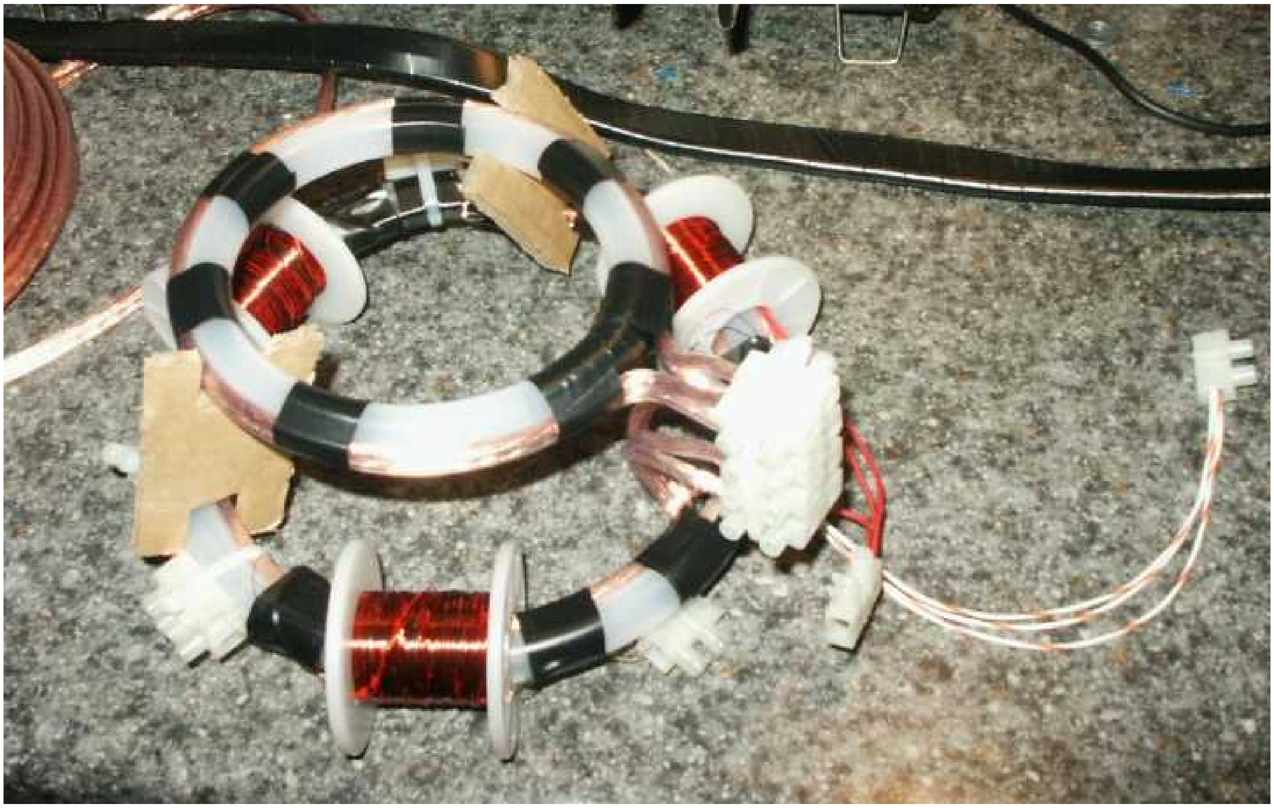
There were also a number of links to videos, but none of them worked - the videos had been removed from the Google video site. Furthermore, a Wikipedia article on "Motionless Electromagnetic Generator" had been removed. Even if one doesn't believe in the possibility, the article should be there to enlighten the curious about what it purportedly is. ...more suppression?

But the knowledge that the CMBR exists, is energetic and omnipresent, and obviously could be harvested in some manner analogous to a solar collector harvesting visible wavelengths, should serve to dispel the incredulity (including by me) that so far has surrounded such devices.



Original "TPU" Toroidal Power Unit from the PDF file
A pulsed transformer type of CMBR powered generator -
simple to the point of being "Mickey Mouse".

(Shown with outer loop opened)



A replicated TPU. This second maker also says it works.

That the site I found was about a replica is very promising, since it means someone followed the original instructions and got similar results to those claimed by the original maker. The power output was said to be about a kilowatt, but it would soon get too hot and quit working. (With that kind of power going through so little wiring, I'm not surprised!) However, it seems like a great, simple demo unit to start with!

It has a "mobeus strip" coil made of 'lamp cord' - two closely spaced parallel wires. It reminded me of Tesla's "bifilar coil" with opposing parallel wires. It occurs to me that the distance between two typical lampcord wires is somewhere around the CMBR wavelength of 1.8mm. That may have a lot of bearing on the tuning and pickup of the CMBR. This runs in a double loop around two circular forms of plastic hose. Again we see similar features between designs. The pulsed control coils are vertical, again at 90 degrees to the horizontal collection coil. And the vertical offset of the smaller inner collection coil gives it a profile similar to the hemisphere-dome shape of the collectors of the Tesla and Markovitch units.

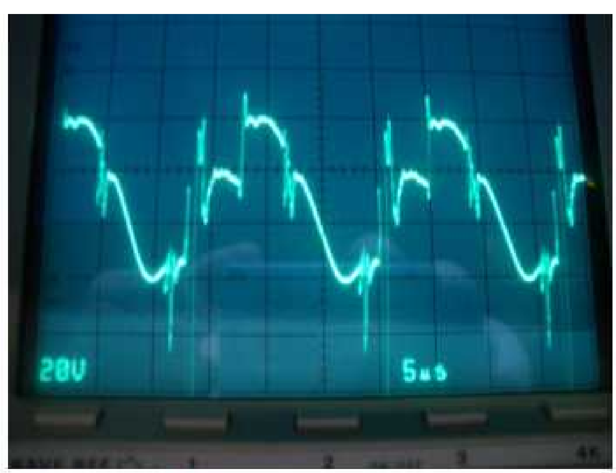


Fig. 42 (06.02.2007 - 15:53) 16" ECD - 3 CC and 2 Frequencies - parallel connected - almost full conversion

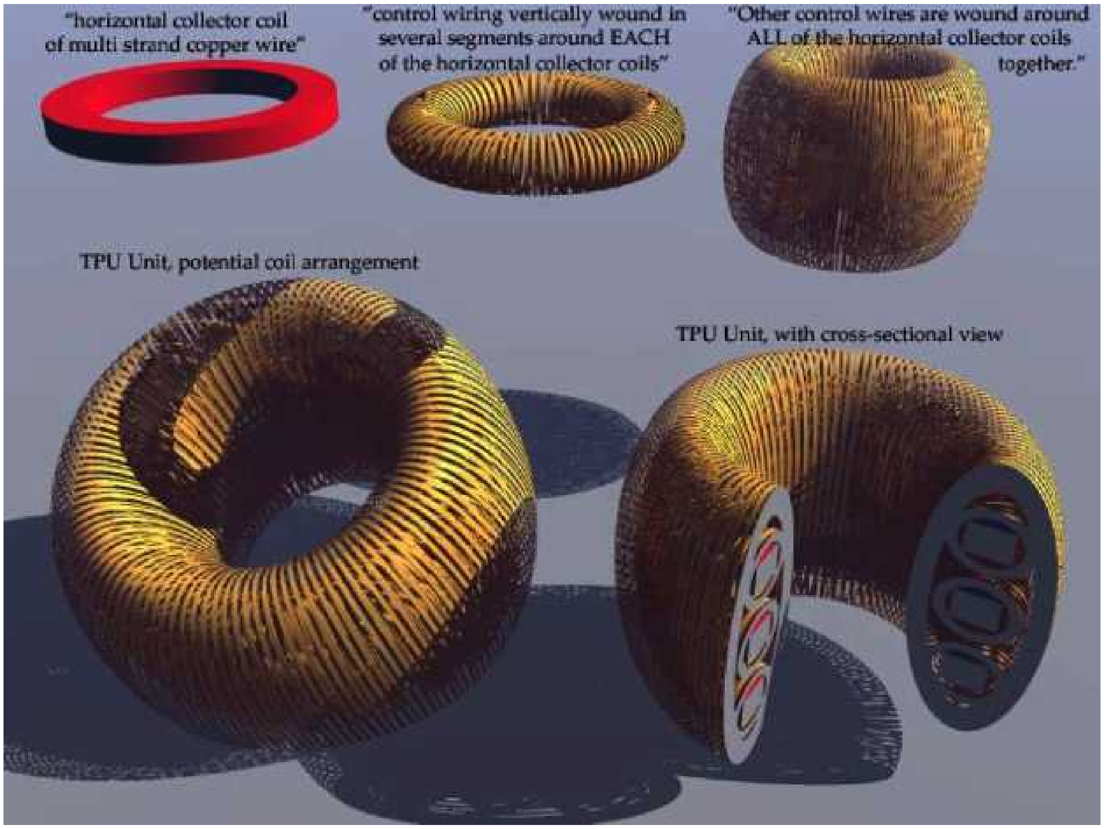
The operation of the unit is quite complex. I assumed the three control coils/transformers were energized in sequence to create a rotating magnetic field like for a motor. In fact, it appears that they're activated at two or three different frequencies, which would create a complex, not to say chaotic, pattern. The authors show many intricate patterns of signals they viewed on the oscilloscope. Somewhere in the correct relationship between frequencies must be hidden the heterodyne frequency interactions to convert 160 GHz to the sort of frequencies transformers and electrical devices can handle. (The frequencies used were in the x100KHz range, and could probably be

synthesized, adjusted, and held at stable values more easily with a microcontroller than with two or three discrete oscillators.)

Another feature saying some strange things are happening was that the heatsinks for the MOSFETs, placed near each driven control coil, got hot. But when the MOSFETs were removed from the heatsinks, they ran cool, while the heatsinks remained hot. This would be owing to the powerful magnetic field that was being created (as mentioned), that they were within. The authors said it didn't work until the aluminum warmed up, and felt that not only electrons but aluminum ions must be whizzing around the unit acting as a particle accelerator. I'm not so sure.

Someone wrote in (to the 'freetesla' web site) that the device was merely a tank circuit with coils and a capacitor, that would have some specific resonance frequency. Of course, if that resonance was at about 1.8mm/160GHz (or perhaps some subharmonic thereof?) it would be tuned to CMBR energy.

I decided to try to make the unit as a 'proof of concept' demo.
This is as far as I got in September.
The electronics will be more of a challenge than the coil assembly.



Another idea of a pulsed TPU. Looks a lot more intricate to make.
Has the same idea of control coils at 90° to the single winding collector coil.

Abandoning other electrical generating projects?

CMBR sounds like a very worthwhile, cheap continuous source of electricity, so despite the challenges I'll probably try to build one - especially having found a design with relatively complete instructions that's been successfully replicated. If I do, I think I should definitively abandon at least a couple of other electricity generating projects rather than simply add a new one to an ever growing list. In consideration of that:

Ocean wave power is a project that should be done on at least a town-wide scale. It requires not only funding but decisions about waterfront and foreshore land usage... by people who don't seem to feel making such decisions has anything to do with them, or who are averse to making decisions that could get BC or Canada into a position of technological leadership. Apparently no likelihood of a smashing success that would enhance the energy future for everyone (and bring in ongoing revenue) is worth risking having a few small failures - learning curve experiences - for. So far it's always seemed to be like trying to row up the rapids to get anything happening. It would also be a 'power grid' source for which under prevailing conditions people would be billed monthly, probably with no benefit from it being cheaper to produce. Especially now owing to the the good chance that nothing would be working before the financial system collapses, ocean wave power seems like a good one to drop.

Geothermal power would be another example of a highly promising community energy project, but obviously very difficult for an individual or an unsupported small group to implement. Promising and unpromising regions in BC and Canada to drill have been roughly mapped out, and even at least one dud oil well, already drilled, had the requisite boiling water temperature at the bottom. (It was filled in again by the oil company. Like I say, the corrupt are almost alone in having plenty of money - your money and my money - to do these things, but they don't want people to have cheap energy.) So far the required support hasn't been forthcoming in Canada to any group trying to push for geothermal power. (This is a highly promising area I've managed to not get involved with in any way, so there's nothing for me to drop.)

Catalytic (or "cold") fusion sounds interesting, and it may work, but again developing it would doubtless be a major task for a dedicated group, and then it would likely be another 'charge per KWH'

technology. (Another one for me not to take up!) I do like the idea that traces of several elements including silver were found after the fusion, since cheap silver would improve the performance of motors with 10% less heat in the coils than with copper.

On the other hand, there are several forms of energy that are free after small, even individual, capital investment in the equipment and or development. In this category, solar, wind and woodstove thermoelectric electricity are time and weather dependent, although in some respects complementary weather-wise. Magnet machines and "space energy", if they can be effectively harnessed, generate continuously, and hence are substantially more valuable for any given 'nameplate' watts rating.

"regular" solar I already have working. I've never tried my "sand pebbles" nanocrystalline titanium dioxide frit to cover solar collector cover glass with little lenses and improve daily solar collection by 20-40%, nor have I tried out ideas I have for better dye-sensitized solar cells. But if "CMBR converters" or magnet machines work, solar collectors seem like good projects not to expand further on, especially here on the cloudy west coast. (Dropping further expansion of "solar" wouldn't mean dropping the low voltage wiring system infrastructure & equipment projects. They aren't specifically solar related except insofar as that's what's presently powering the system.)

The vertical axis wind turbine I now have the parts for, and putting them together poses little theoretical challenge. It could perhaps put out several hundred watts in a good wind... but not much for 90% of the time. I can do a "nowhere man" and set it aside until somebody else wants to lend me a hand with it.

The woodstove thermoelectric generator as I have wished to implement it needs an evacuated tube radiator and a pressurized tube radiator. The evacuated tube needs to be done for other thermoelectric projects as well. The pressurized one should be simple enough in principle, but implementation with the TEG module heatsink plates is looking tricky. And it'll only put out around 100 watts for a considerable investment in TEG modules and heatsink & plumbing components. It might be a good one to set aside -- and then abandon if the 'space energy' converter makes as much or more electricity.

Since they seem so promising, even if highly challenging, I guess that narrows it down to magnet machines and "CMBR" harvesters, with the wind turbine when it's convenient. The rest I'll probably drop unless I get nowhere with either of these for a considerable period.

Electricity Storage - Turquoise Battery Project (etc.)

Main Discovery Points for September:

* Using a strip of zinc as a comparison electrode in discharge tests, it was noted that at no point of discharge down to 1.5 volts was the manganese negative electrode equal to or less negative than the open circuit zinc electrode. There's some level of uncertainty because the readings on the zinc electrode kept varying, by as much as 1/4 volt, but taken at face value this means (a) that most of the decrease in voltage during discharge is occurring in the positive electrode (so the negative has substantially more effective amp-hours - which is theoretically the case - and or better substance utilization, also likely), and (b) that it should after all be okay to discharge the cells to 1.5 volts or less: the zinc shouldn't oxidize.

I'd want to test this further and check the zinc terminal strip for corrosion and the posode for changes over time from such big changes in oxidation state, but if it's okay, that gives many (up to 67%) more amp-hours if one is willing to accept 9v from a six cell, nominally 12v battery that charges at almost 18 volts and has over 15 open circuit volts when fully charged. Again, a DC to DC converter might be employed to regulate the voltage. When the cell was accidentally run down to 1.29 volts, the negode voltage did appear to fall to the zinc voltage, so there does appear to be a limit somewhere not too far under 1.5 volts. It will depend on the ratio of active substances between electrodes, but these remarks should apply if "+" and "-" are the same volume, which gives considerably more amp-hours of dense negative material than lighter positive nickel hydroxide and permanganate.

* So far, I haven't been able to get a manganese electrode in a cell at pH 14 (in KOH) to charge and hold its charge, even if the cell is cool, eg in a fridge. (My own electrolyte varies from pH 7 to 12 or 13, seemingly drifting towards the upper ranges after a while.) In pH 14, the zinc test electrode is more negative than the "Mn" negode under load, so only the zinc 'conductivity additive' is charging and discharging.
An electrolyte of KCl + KOH with enough KOH to raise the pH to 14 (or maybe it's just 13+) still doesn't work. Theoretically pH 14 won't oxidize the nickel plating on the posode pockets as a lower pH would. If it worked okay, Changhong batteries could probably make NiMn batteries of over 2 volts on their existing NiFe/NiCd 'Edison cell' production line (purchased from Varta). So far it doesn't look like that's viable.

* The MnMn cells hold more voltage and energy longer as they age or as they're charged, discharged or cycled. It seems to take some weeks, but the self discharge gradually decreases. (graph below.) If this is what needs to be done to get them working, it's worth the wait for the performance. If however the posode is disturbed, considerable self discharge returns and the process must start again. In the one case of this so far, the self discharge returned after I opened the cell and replaced the broken graphite terminal sheet/strip, removing the old one and slipping a new one into the electrode behind the perforated graphite collector sheet.
The process has continued into October and I'm expecting the self discharge to drop to trivial or at least easily workable levels within maybe 3 months.

* The batteries are now effectively working, but from the amp-hours attained, the utilization of the active substances seems very low, perhaps only around 2 or 3 percent. Here is one more number that should be multiplied by 10 or so before the cells will compete with lithium ion in energy density. I don't understand why it's so low. Back in my researches I have had batteries that have put out an amp hour or so instead of 1/10th of one, if only at voltages below a volt. And in fact, these ones put out far more amp-hours if run down to a volt or less too, but that corrodes the zinc collector plates. At this point, it might be well to try to interest a manufacturer such as Changhong, since they may well be able to solve this problem without further effort on my part. But perhaps in making a few more cells I'll get better at it or figure out something.

Nickel-Manganese Alkaline Cells

It occurred to me that it might be just possible that manganese negodes with both antimony sulfide and zirconium silicate would hold their charge in alkaline (pH 14) electrolyte. The -1.57 volt reaction potential would definitely stretch the limits of what's possible. If it worked, Ni-Mn cells just might be makable by Changhong batteries on their existing Ni-Fe/Ni-Cd assembly line, which could make 2 volt alkaline cells available quickly. Theoretical cell voltage would be +.49v - -1.57v = 2.06v - identical cell voltage to lead-acid.
I tried it out using the case and nickel electrodes of a Changhong NiFe cell. It seemed to take a charge, but then to lose it again. I put it in the fridge and it seemed to hold it better, but still lost it overnight. Furthermore, the voltage dropped below the nickel-zinc charge voltage, so it wasn't just the manganese that wouldn't stay charged.
So I rinsed the electrodes and changed the electrolyte, which had been sitting in the cell and not sealed from the air for quite some time. The Mn electrode had broken up after it was made, and it was made up of these broken pieces. A couple of them fell out during the rinse - not a very auspicious sign! But I hadn't tried to seal the top, only the sides and bottom. My plan had been to not fill the liquid to the top. I didn't see any rips. S.G. of the KOH was about 1.2. When I put the cell back together, the voltage was 1.95 volts: evidently the zinc was metallic, but the manganese, by and large, wasn't. The liquid was still quite warm from mixing in the potassium hydroxide, and the Mn wouldn't charge. With 300mA going in, it stayed just under 2 volts. I put it in the fridge. A while later I unscrewed the filler cap assembly and stuck a lab thermometer in the hole, so I was monitoring the voltage and the temperature of the electrolyte - about 22°c and 1.966 volts, ~300mA.
One hour: 16° - not charging. With the charge removed, the cell soon dropped to 1.87 volts - lower than when first filled, but reasonable for nickel-zinc. This would be the minimum voltage to allow during discharge - call it 1.9 volts - in order not to start corroding the zinc current collector.
But why was it now working worse than when I'd first put it together? It wasn't taking any sort of

charge above zinc level, but it had when first made, even at room temperature. The only thing I could think of was that I had tightened, a little, the tie-wraps pulling the electrodes together. But if that had caused a short, why would it hold any voltage?

1-1/2 hours, 12 degrees, still no changes to voltage and current. 2 hours, 11°, still nothing. Overnight, 4°, still just nickel-zinc. What the bleep? All I'd done as far as I knew was change old electrolyte that probably contaminated with carbonate from CO2 in the air for a fresh batch. The devil must be in the details somewhere. Maybe I should have hung onto the old electrolyte to see what was in it!

So far, pH 14 and Mn negatives don't seem compatible.

MnMn Too... finally holding a charge

While I worked on the NiMn-alkaline idea, I also had my MnMn cell. I rolled out some clay to less than 1/8" thick and formed some into a ceramic 'box' with an open top, sized to put one of my electrodes into, as well as a couple of thin flat sheets. It was porcelain clay ("Laguna B-Mix cone 5"), but I only fired it to cone 06 (80 minutes in my mini kiln) which made it a porous ceramic (Earthenware). The fired thicknesses measured about 1.5 to 3mm - not very uniform, also pretty thin for pottery.

I hoped the fine pores would allow chlorine and hydroxide through but block the heavier permanganate ions. I fired these on the 5th or 6th and put the posode in the box and into the cell on the 7th, with the liquid not quite up to the open top of the box. On the night of the 7th-8th things didn't look very promising: the cell held 2.16 volts or so overnight. At least it was better than 1.95. I charged it heavily a while in the morning. The lab smelled of chlorine: the ferric chloride if not the potassium chloride was gassing at the high charge voltage. I then went to do a 20 ohm load test. It worked nicely for a few minutes, then I was interrupted by someone at the door. I forgot about the battery for over an hour, and when I came back it was down to 1.3 volts - oops. I put it back on a low charge and left it.

In the evening I disconnected it and it was soon down to 2.54 volts, but then ticking off the seconds per millivolt of drop, it looked promising. By morning, the 9th, 8 hours later, it was still at 2.38 volts. It didn't have much high voltage energy left and only put out 40+mA into a 50Ω load for 4 minutes before dropping to 2.0 volts.

But it was much the best charge retention so far. If it continued to improve, if it held 2.5 volts, it could be a usable energy storage battery. The ceramic didn't seem to have helped much the first night. Was it improving because of charging and the various things I had done deliberately?... something to do with the gassing off of chlorine?... or was it because the overly heavy discharge had released zincate ions, which then perhaps spontaneously turned into Zn(OH)2 or ZnO and clogged the pores of the ceramic? Was the pH becoming more alkaline if the chlorides were gassing their chlorine? It was now rather difficult to take the top off and measure pH because the heavy clay box didn't turn with the lid and the electrodes were getting twisted. Perhaps further trials over a few more days before I risked that...

That afternoon the cell seemed to be holding voltage even better than the previous evening. Something seemed to have happened that was now slowing the self discharge. A load test also revealed that the internal cell resistance was higher. From 2.55v the voltages dropped lower with a 20Ω load test (under 2.3v almost immediately) and showed only 40mAH, but from1.85v after 21 minutes it recovered to over 2.45, and could then run a 50Ω load with good voltage. (I only ran it for a couple of minutes - it might have gone 10 or more.)

The cell seemed to have fairly even performance over the next weeks, capacity going up or down depending on charging conditions and how long it sat after charging before a load test.

Self discharge/pH/permanganate trapping clues

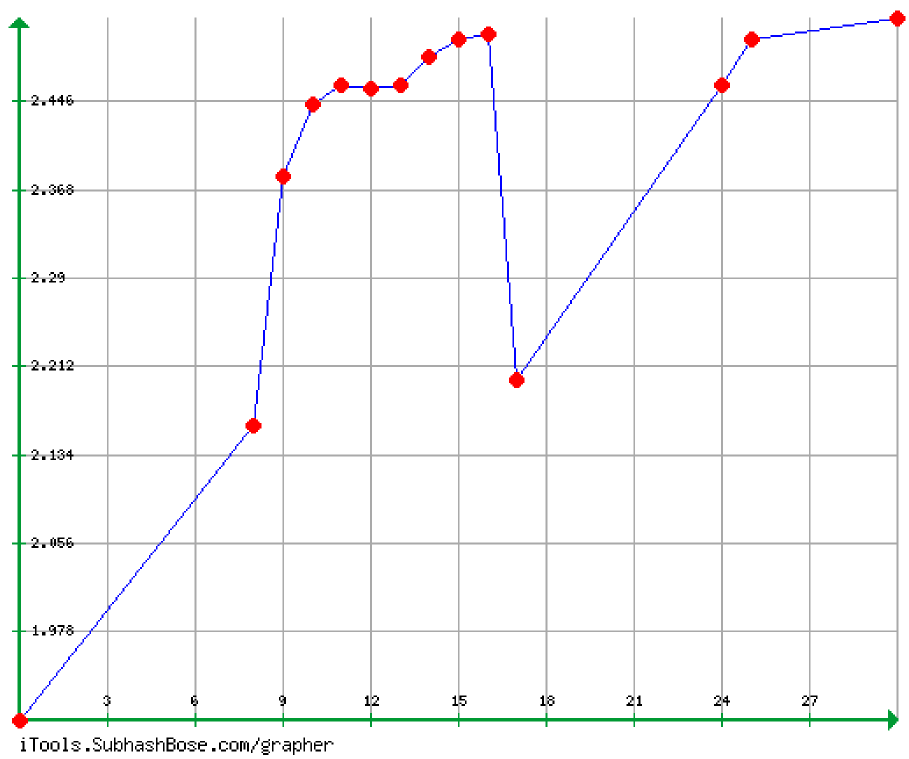
Over the next few days it appeared to be holding about 2.46 volts for 8 hour periods. On the 14th it was up to 2.485. It still didn't run at over 2 volts for very long even with just a 50 ohm load, but the periods slightly lengthened each day, for example hitting 7 minutes on the 13th. On the 14th I ran it down to 1.7 volts over 40 minutes - still just 27 mAH. The zinc strip still measured about .2 or .3 volts less negative than the Mn negode. On the 14th-15th it held just over 2.50 volts for over 8 hours and delivered a few more mAH in the morning. In the afternoon after charging a while, it ran 33 minutes down to 1.9 volts with a 25 ohm load. (Of course it would have considerably run longer if I had

drained it down to 1.7 or 1.5 volts.) Each few hours or a day seemed to disclose further gradual improvement in performance.

Until on the 16th I opened it to check the pH, which I had wanted to do for some time. It was pH 12 - excellent place. But opening it disturbed the connections to the posode, and twisted things around a bit. I found that high self discharge had returned, notwithstanding that there was no apparent disturbance to the ceramic holder. This meant it [probably] wasn't the pottery that was preventing the self discharge, but more likely something building up over time and changing in the surface of the electrode itself, that was 'gluing' the permanganate into the electrode. That would probably be related to the organic sulfate and sulfonate compounds in the 'Lemon Fresh Sunlight' dishsoap. When that internal 'skin' is disturbed, the self discharge comes back until it heals. As the end of the month approached, the self discharge was down quite a bit, holding 2.50 volts for about 12-14 hours on the 29th.

Other likely factors for gradual change and improvement are (1) the addition of the ferric chloride, painted onto the electrode and (2) the possibility that the nickel hydroxide and the manganese dioxide were charging together to some compound such as nickel manganate.

I think next time rather than the ceramic, I'll try 2 layers of the heavy watercolor paper around each electrode instead of one, again with a piece of coarse macramé cloth in the middle. At least that's nowhere near as thick as a ceramic wall, so the current capacity should be a lot better. (I _should_ try this in a new cell, to make sure the ceramic truly isn't required.)



Self Discharge Chart: approximate voltage retained after about 8 hours sitting, during September.
Below about 2.50 volts open circuit, the cell has little retained energy and will rapidly drop below 2.0 volts delivering a load.
After opening and disturbing the cell on the 16th(?), the chelation process had to partially start over again.
First readings after assembling the cell were about 1.9 volts; final one is about 2.52 volts.
2.55+ after days instead of hours would be a lot better. It'll probably get there.

Lower Voltages without zinc corrosion?

On the 11th I contrived to slip a thin strip of zinc down the end of the slot for the negode terminal, so that I could measure the manganese negode voltage with respect to a zinc negode's open circuit voltage. To my surprise, at all times during a long discharge, it read at a minimum about .2 volts more negative - even when the discharge voltage was down to 1.5 volts. This would seem to mean

that the manganese negode is holding its charge throughout, and it's mainly the plus side that's decreasing in voltage as discharge proceeds. It must be the one holding a low value of higher voltage amp-hours, and discharging through nickel oxyhydroxide (if that's charging up at all) and potassium permanganate to nickel hydroxide and manganese dioxide starting at 2.4 cell volts, then the MnO2 discharges to Mn2O3 at under 2 volts, then to Mn3O4 dropping to around 1.5 volts or less, and ultimately to Mn(OH)2 at around a volt. Disregarding the apparently pathetic percentage utilization of the active substances (but maybe only of the "+"?), this does actually make sense in that the heavier negode worked out to far more theoretical amp-hours than the posode.

This means the cell can (*should* be able to) discharge to much lower voltages without oxidizing the zinc structural material. One could after all consider 6 cells for a nominal 12 volt battery, charging to 18 volts, then delivering starting around 15 volts (with a light load) down to around 9 volts without damage if it's useful and necessary.

A somewhat suspicious aspect, however, is rather wildly varying readings of the zinc strip 'electrode', with readings often swinging from .2 to as much as .4 volts more positive than the manganese. If the actual case is anywhere in there, it's fine, but the variations cast some doubt on the validity.

However, on the 26th I accidentally ran the cell down to 1.23 volts, forgetting about a 25 ohm load test that got left on for about an hour and a half, and the Mn negode voltage was then about equal to the zinc voltage, meaning the manganese was pretty much discharged and now the zinc was discharging. This shows that there is a lower safe limit, seemingly somewhere below 1.5 volts. This accidental run-down seemed to improve cell performance a bit, perhaps by zinc ions redistributing and making better connections with the -Mn particles. After a while however the zinc terminal trip would oxidize away and the cell would quit working, as with cell PP#2.

Nickel-Manganese: in KCl-KOH Cell

Before mid month I decided to try Ni-Mn in something other than caustic KOH electrolyte, in which the Mn negode didn't seem to hold a charge very well. Rather than make a new cell, I emptied the KOH from the Changhong attempt, and refilled it with KCl electrolyte with enough KOH added to bring the pH to 14. pH is a weird thing. It doesn't take much to swing it wildly from extreme acid to extreme alkali, even while neutral salt is the bulk of the solution. _Theoretically_ the nickel plating wouldn't corrode off the nickel hydroxide electrode shells. Also _theoretically_ the Mn wouldn't hold a charge any better than in straight KOH. But on the 13th I tried it anyway since it was simple to do. The initial voltage was about 1.74 - nickel-zinc voltage from the zinc structural parts of the electrode, with the manganese completely discharged.

I put it in the fridge and started charging it at 150mA. The voltage rose slowly, but it seemed hard pressed to bring it up above about 2.0 volts, and it soon dropped back to just over 1.9. Theoretical cell voltage was 2.06, so it should have gone at least a little above that on charge.

Subsequent placement of a zinc strip confirmed that the voltage didn't stay much more negative than zinc: essentially the manganese wasn't charging, and it soon lost any charge that it did take.

I didn't get around to making a fully homemade Ni-Mn cell with a lower pH, having redirected my main energies around mid month towards studies of devices to convert free CMBR energy to electricity.

Soldered NiMH Battery Packs

Replacement Soldered Battery Pack for e-Bike. Tarpaper replaces 'built-in' cardboard of original cells.

I made up a soldered NiMH D cell pack for an e-bike, and then re-did an earlier one for a cordless electric lawnmower. Notwithstanding my reluctance to make soldered packs after previous experiences, nothing else was going to fit on the bike.

I noticed the original cells had cardboard under the plastic outer cover. Aha! There was one part of the answer: if the pack overheated and the covers melted, at least the cells wouldn't short circuit against each other and cause the whole pack to go up in smoke, with the risk of fire or injury.

I judged that the other thing I had been doing wrong was soldering heavy flat "bus bar" wire to

connect the cells. It *seemed* the most solid, but the solder joins kept breaking with bumping and vibration under the weight of the cells. If instead I used lighter, stranded wire, the cells could move a bit against each other, and the wire would flex instead of putting stress on the solder joint.

Tarpaper sheaths taped around each cell and thinner, stranded wire should solve the two main problems I had been having with soldered packs!

For the bike pack I used #14 stranded wire, thinking of the heavy currents that would sometimes flow. But I began to realize that the solder wicked along the wire too far, making it much less flexible. For the lawnmower, I switched to lighter #16 wire. It soldered more quickly so the solder didn't travel down the wires much, and everything was much more flexible. I also used insulated wire, to make really sure no wire could short somewhere against a case part.

24V - 20AH cordless lawnmower battery pack (one 12V - 20AH half): wiring with flex should handle vibration best.

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http://www.TurquoiseEnergy.com
Victoria BC

Radio Frequency Experiment by BH1RBG

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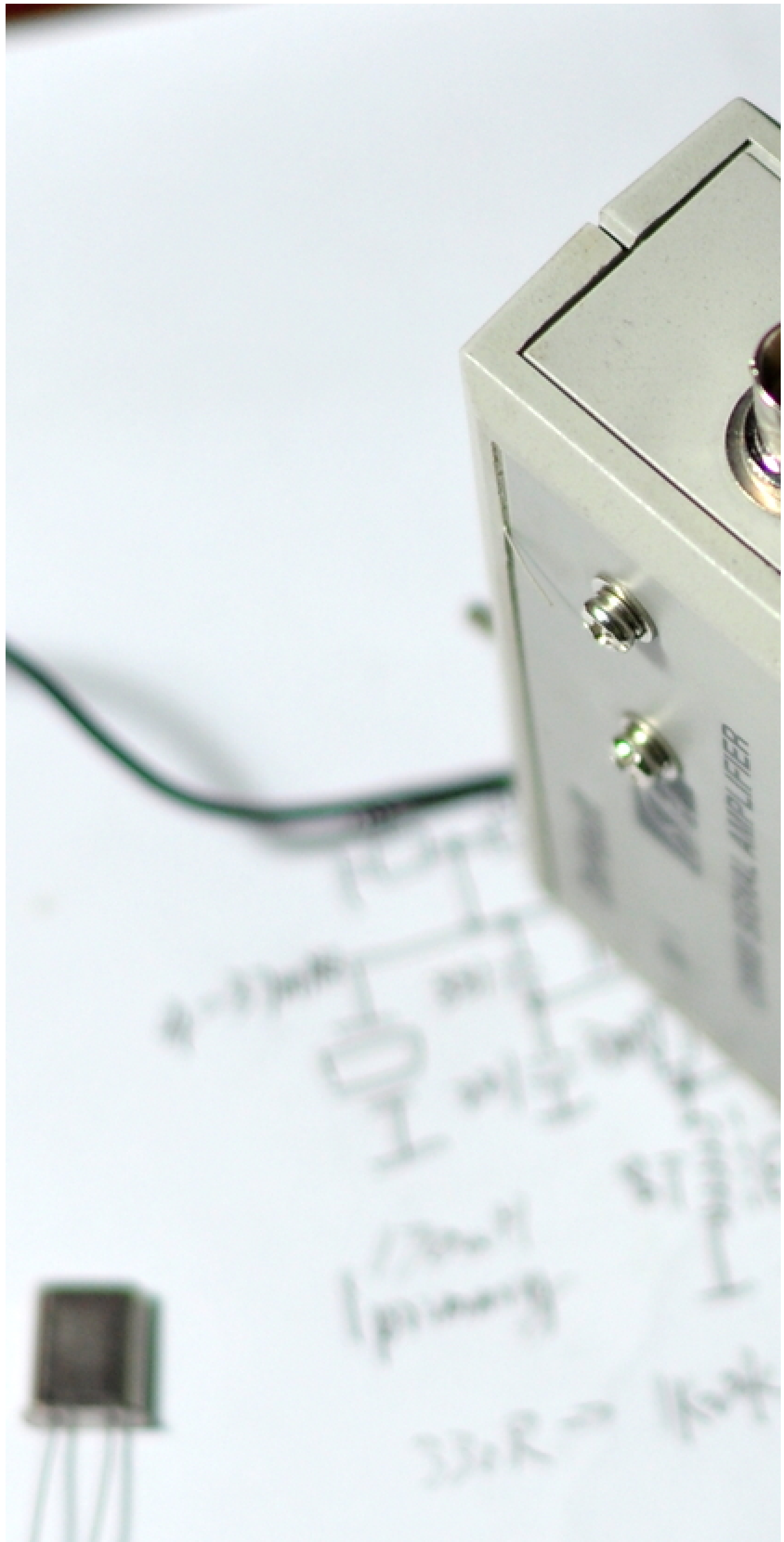
Crystal: checker

2013/7/14

i have many many crystal whose mark is vanished. Or some time i need now is this a overtone Crystal?

so i need a crystal checker use fundamental mode oscillator. The requirement is, oscillation from 1Mhz to 40Mhz (i did find a 36Mhz fundamental crystal, may be it's not, but always start at 36Mhz on a fundamental oscillator)



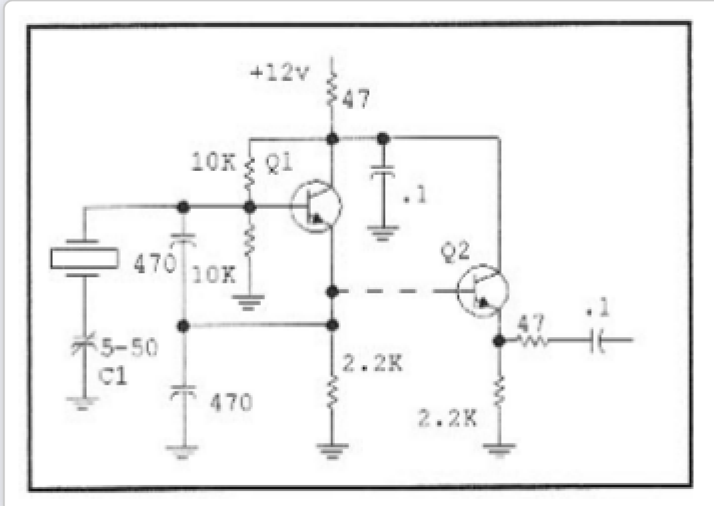
*internal, 2X LiPo as supply
*built-in charger : simple charger
*1Mhz to 8Mhz, 4Mhz-40Mhz, fundamental

Contact me

heyongli@gmail.com

<<EMRFD>> given several oscillator of crystal. i think the popular Colpitts version is suit for such a simple device.

Fig 4.23



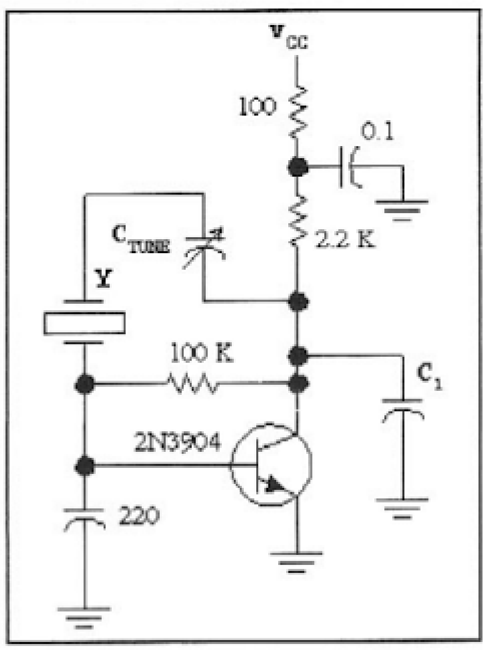


Fig 4.25—Pierce type crystal oscillator. C1 can be as little as 10 to 20 pF. Vcc can be from about 3 up to 15 V. C_{TUNE}, often omitted, is a trimmer with a maximum of 50 or 100 pF.

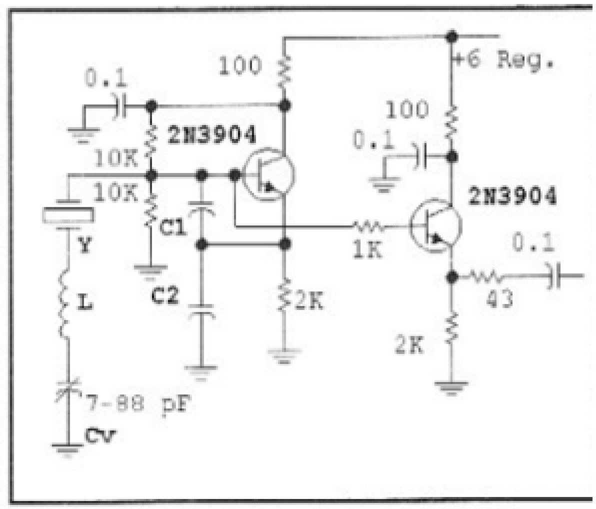
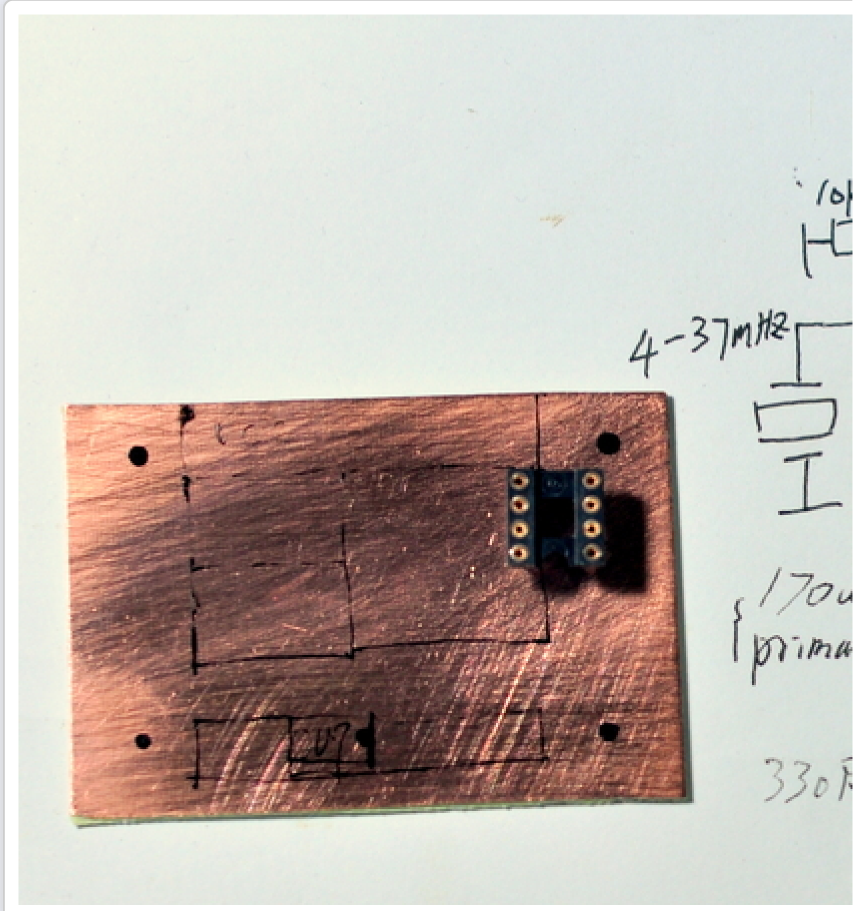


Fig 4.30—Basic VXO circuit. C2 is typically twice C1, which is 100 pF at 10 MHz and higher, doubling for 7 MHz. L is determined by experiment. C_V can be about any variable capacitor, but should be one with small minimum capacitance. L may = 0, 2.7 µH or 5.4 µH.

The Fig4.23 is identical to right one if you remove L, CV from Fig4.30.

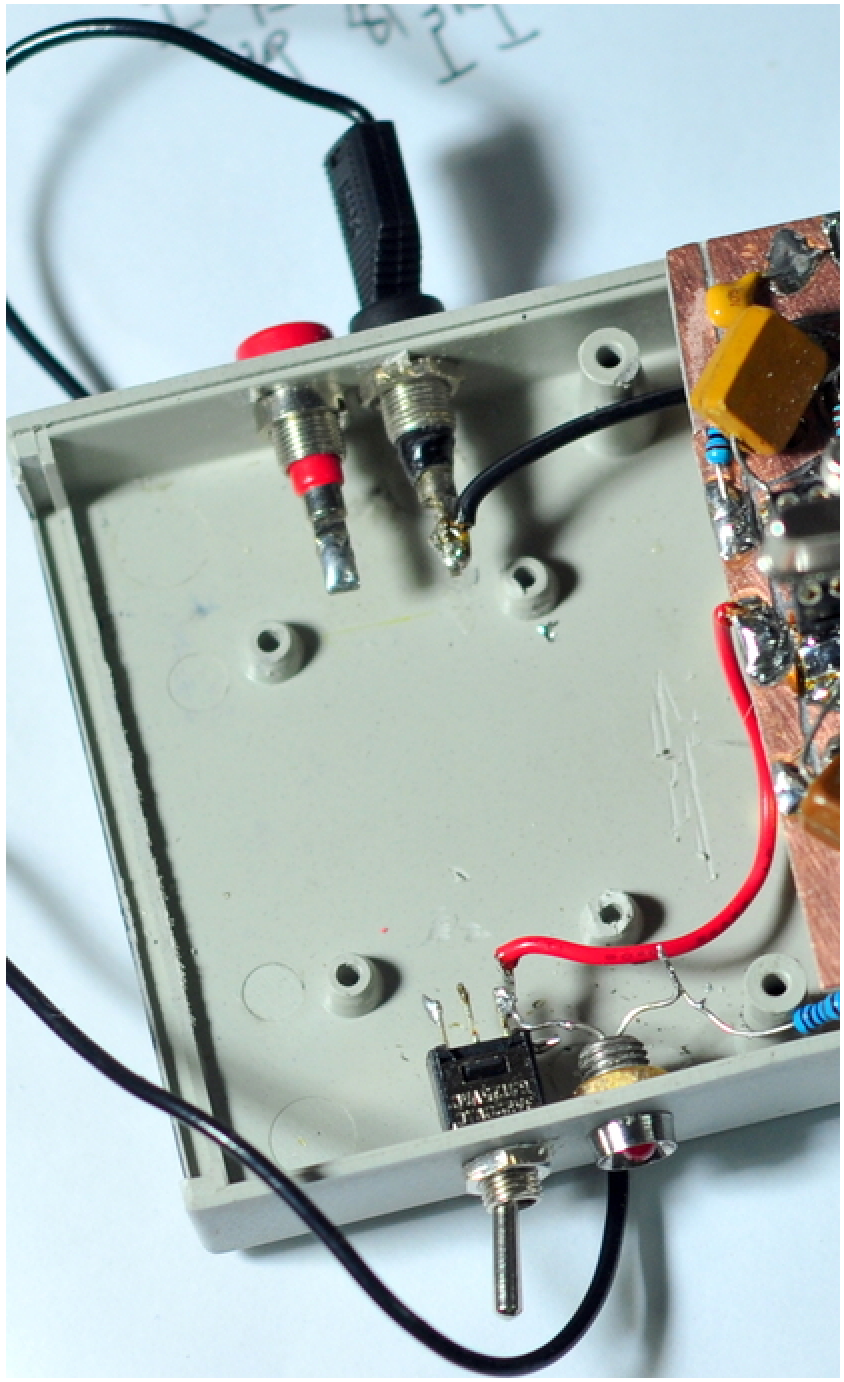
Fig4.23: 2-20Mhz fundamental mode. Q1 2N3094.
Fig4.25: 2-20Mhz fundamental mode. Q1 2N3094. C1: 10-20pF   output: few milliwatt. a variation of Colpitts.
Fig4.30: VXO

I actually built my version start from Fig.4.30, but NOT a VXO, remove L,CV,and no buffer. but insert a 16:1 impedance transformer(8T:2T) to emitter of oscillator. I use a very cheap **ferrite Toroids**: which extract from a **fluorescents light**, this just a checker, so such a toroids good enough work from 1Mhz to 30Mhz.   8T in primary about 170uH.



for high frequency: 4-40Mhz
change 2k emitter resistor to 330R(1k might work not test), which about 10mA. C1, C2: 200pF

for 1Mhz to 8Mhz
to reliable start, around 1Mhz, this emitter resistor must at least 1k, or more, otherwise low frequency not work. C1, C2: 1000pF



Comments

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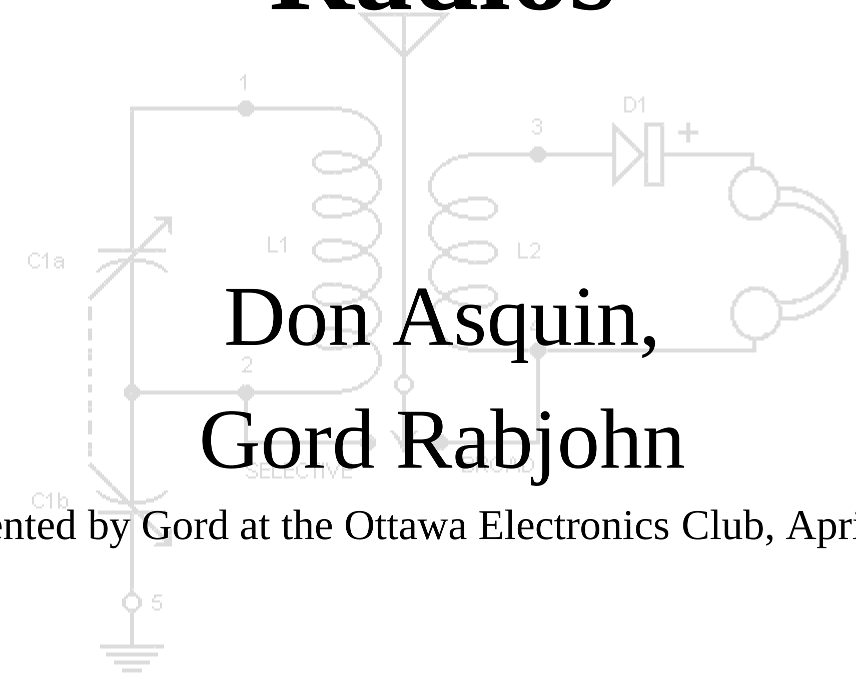
High Performance Crystal Radios



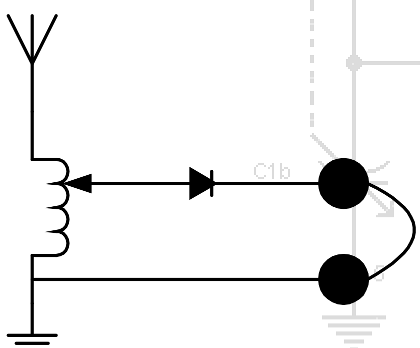
Don Asquin,

Gord Rabjohn

(Presented by Gord at the Ottawa Electronics Club, April 2012)

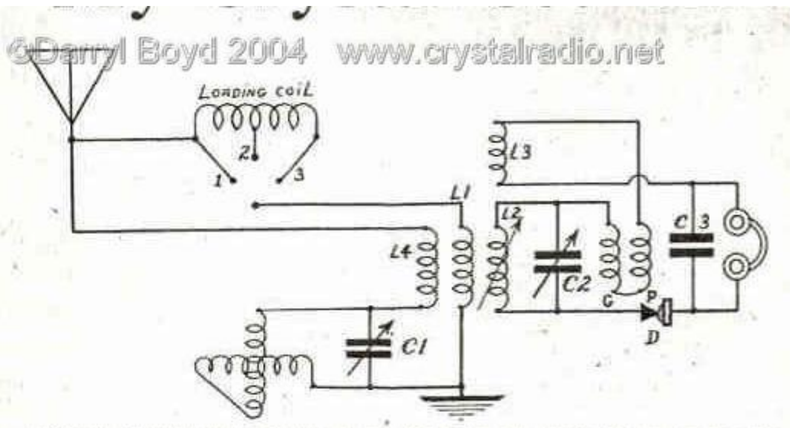
Childhood History

www.crystalradio.net



- Like many kids, I had frustrating childhood experiences with crystal radios!
- Simple crystal sets couldn't separate multiple AM radio stations.
- Only local stations were received, and everything was received all at once.

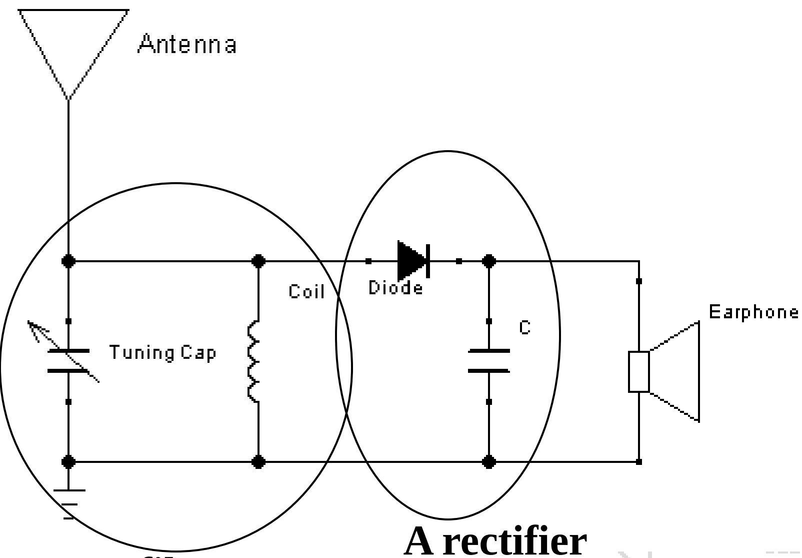
Rediscovering History



www.crystalradio.net

- Recently, my friend Don Asquin and I decided to build high performance crystal sets.
- Much of this exploration is rediscovering the knowledge of the 1910s and early 1920s.
- Even then there were claims of DX performance with crystal sets.

How does a basic crystal set work?

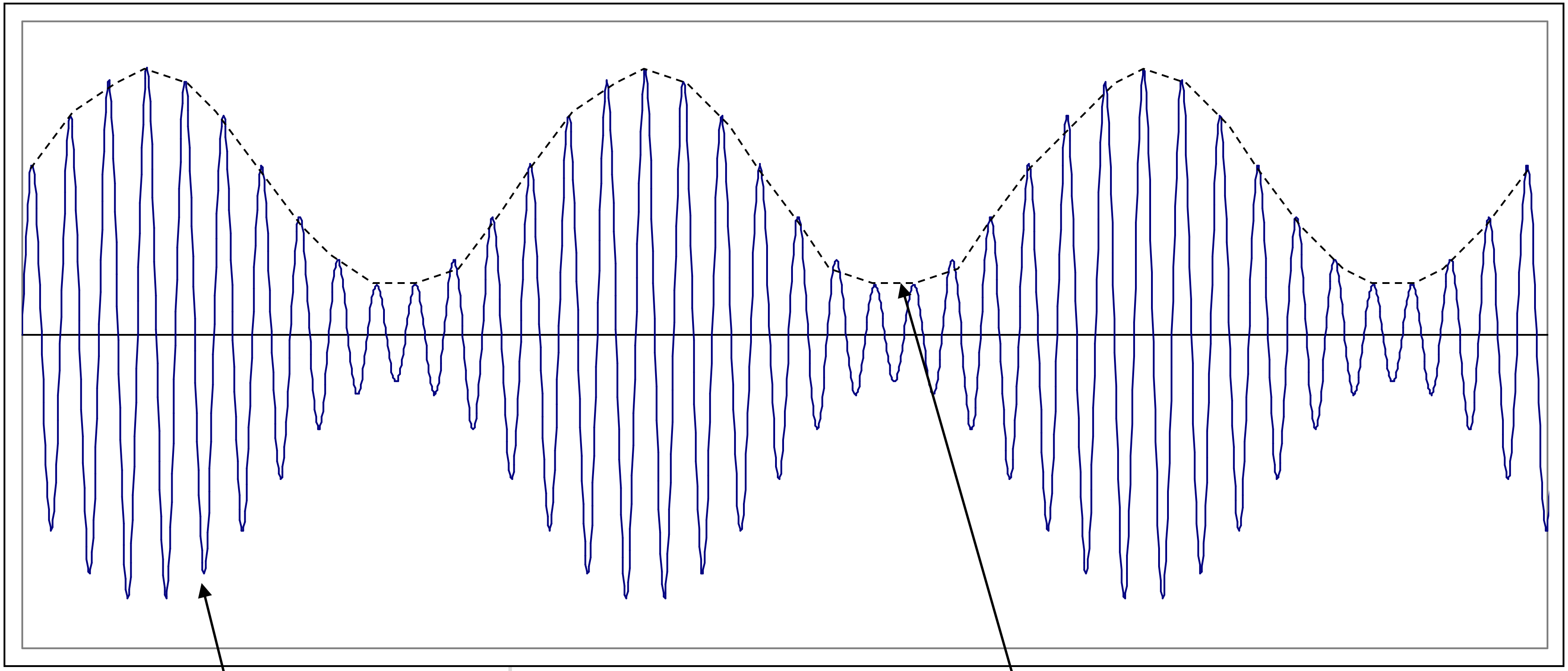


A rectifier

A filter
At low frequency, the inductor shorts the signal out. At high frequency the capacitor shorts the signal out. In-between, there is a magic point called "resonance"

- Antenna couples to the (usually) electric field in a radio wave.
- L-C selects the frequency.
- Diode rectifies it.
- Earphone makes it audible

AM modulated signal



RF Carrier frequency (say 1310kHz): the filter selects only this frequency.

Rectified audio output, smoothed by the capacitor

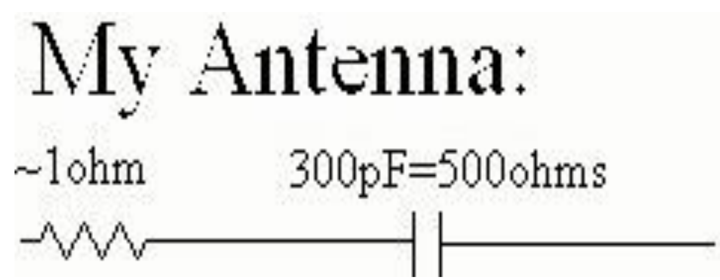
The Four Key Elements

www.crystalradio.net

- Antenna
  - Antenna
  - Ground
- Tuner
  - Loose coupler
  - High Q coils
  - RF impedance matching
- Detector
- Audio Transducer
  - Audio Impedance matching

Antenna

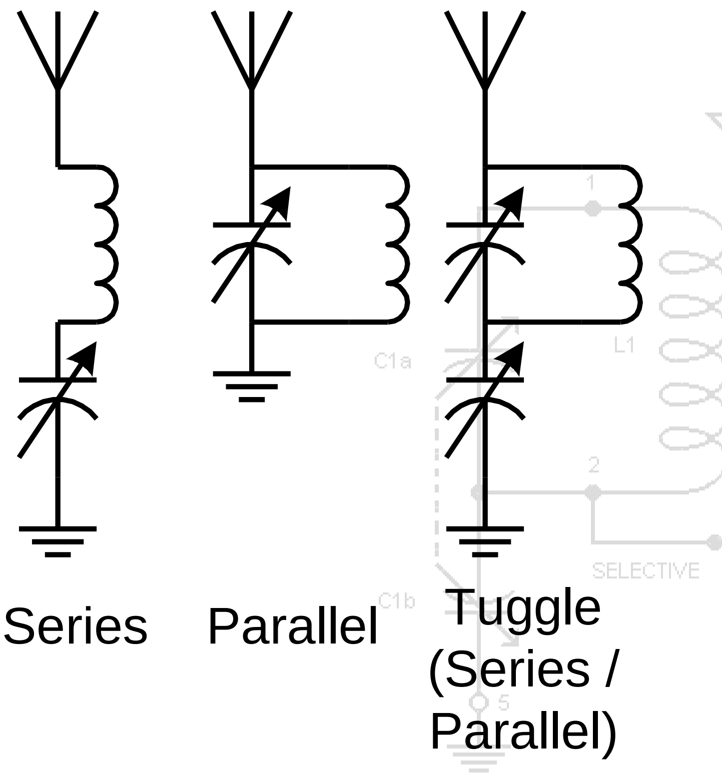
- A long exterior antenna is crucial.
- Why? It’s not just about area… “watts per acre”. It’s also about giving the antenna a better “radiation impedance”.
  - The energy from an antenna, can be modeled as a voltage source in series with a source resistance (or a current source in parallel with a source conductance), and the antenna capacitance (or inductance).
  - Radiation resistance is the resistance of this apparent source of energy in an antenna.
  - The tuned circuit matches this impedance to the load (detector) for optimum energy transfer.
  - A small antenna will tend to look like a “difficult to match” impedance….



⏚ Ground ⏚

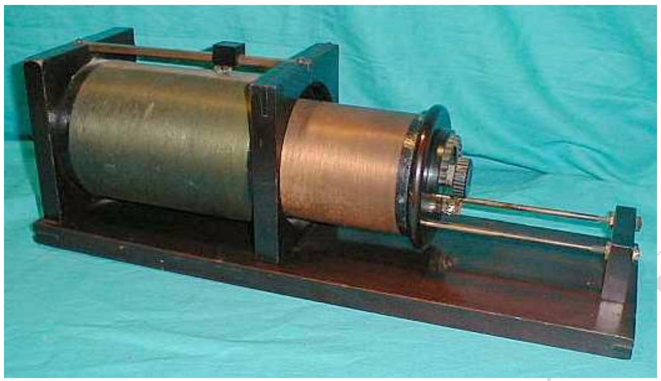
- The ground provides the completion of the current path for the radio signals.
- You can always attach a wire to a cold water pipe, but the best ground remains a copper plated rod pounded into the ground.
- Home Depot sells these rods for grounding electrical systems.
- If installed near a water tap, the ground can be kept moist and conductive.

Tuner
-Antenna Tuner

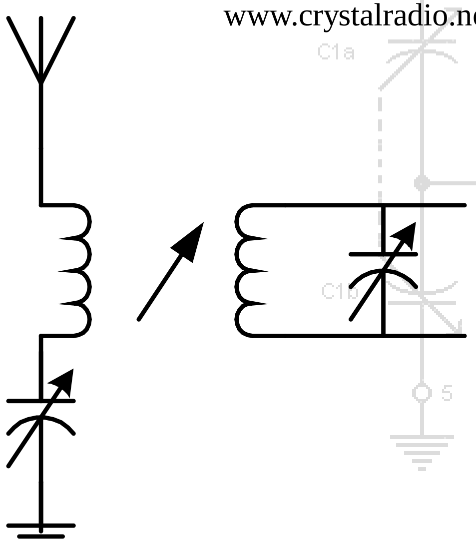


- To extract the most power, you need to match the resistance of the load (detector and earphone) to the impedance of the source (antenna)
- The function of the tuner is to match the radiation resistance of the antenna to the impedance of the detector, and to provide selectivity.

Tuner
-Loose Coupler

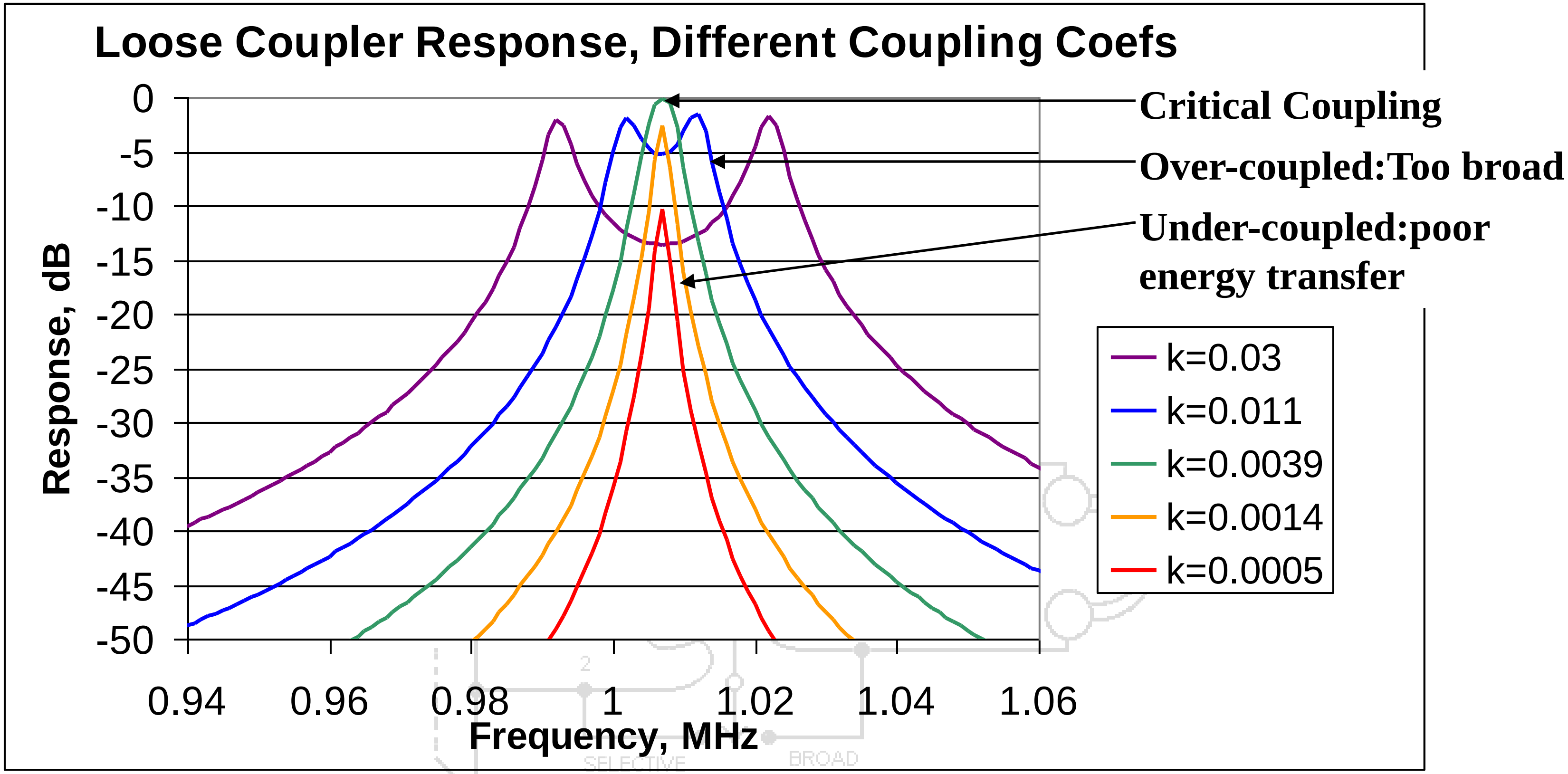


www.crystalradio.net



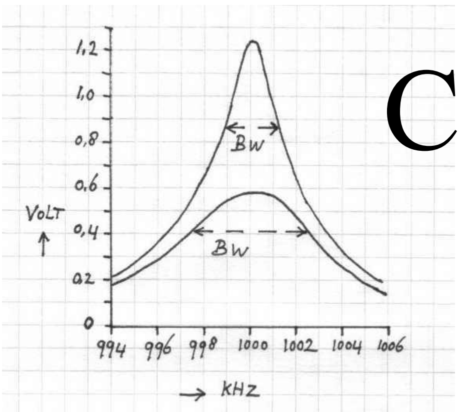
- The loose coupler is simply two coils (each generally resonated with a capacitor) lightly coupled to each other.
- One coil is connected to the antenna, the other is connected to the detector.
- Even cheap capacitors tend to be quite good, but high Q inductor fabrication is an “art”.

Loose Coupler



Simulation of 1000pF, 1.0 ohm antenna, 100uH primary coil and ~330pF cap, coupled to a 100uH secondary coil, 250pF cap, 100k load.

- There is an optimum amount of coupling between the coils. (=1/Q). This is VERY LIGHT coupling. Under 1% of the magnetic field is coupled.



www.crystal-radio.eu

Coil "Q" = Quality

$$Q = \frac{\text{Frequency}}{\text{Bandwidth}}$$

Station Frequency (kHz)	Minimum Q
540	54
1000	100
1600	160

Assume Q=160

Station Frequency (kHz)	Audio Bandwidth (kHz)
540	1.7
1000	3.1
1600	5.0

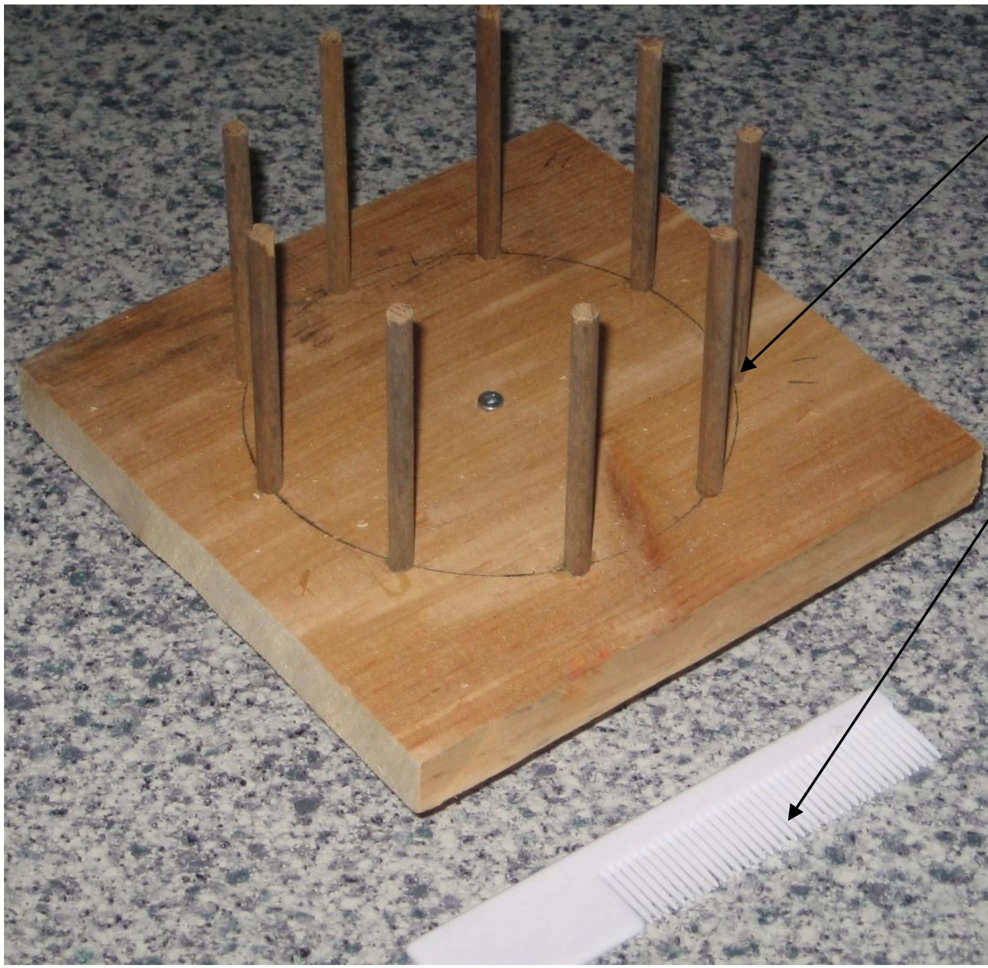
- For a tuned circuit "Q" is the ratio of the center frequency to the bandwidth.
- For a coil, it is the ratio of energy lost to energy stored.
- Q is very difficult to accurately measure.
- You can never have too much Q!
- The inductor is usually the part with the poorest "Q", so a lot of creative energy is invested into optimum devices.

Coil Types

www.wynterarchtops.com

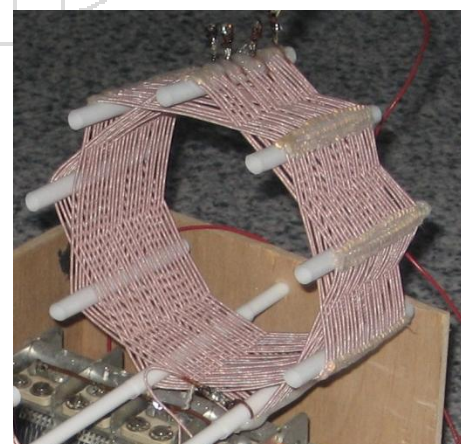
- The highest “Q” coils seem to be air core.
- Many different variations
  - Spider web,
  - Basket weave
  - Honey Comb
- All attempt to reduce capacitance and current crowding to increase Q

Coil Winding Jig

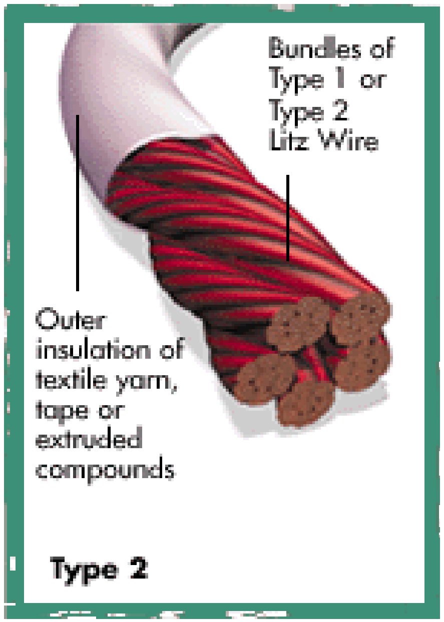


Drinking straws fit over ¼” dowels.

Comb helps space wires



Litz Wire

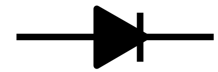


www.newenglandwire.com

- Best wire for high “Q” coils is Litz wire.
- Litz is derived from the German word “Litzendraht” meaning woven wire.
- Consists of many strands of parallel connected, individually insulated wire woven together in a regular pattern.
- Each wire alternates between the middle and the outside of the bundle.
- Each wire forced to carry about the same current, minimizing skin effect (the tendency for current to flow along the outside surface of a wire), and loss.
- The holy grail of litz wire is made up of 420 to 660 individual strands of 46 AWG wire all twisted together to make a 16-18 AWG wire.
- One comparison: A basket wound coil with solid copper wire (~200uH) has a Q of 230 at 1MHz. With Litz wire, it has a Q of over 500!

www.crystalradio.net

Detector

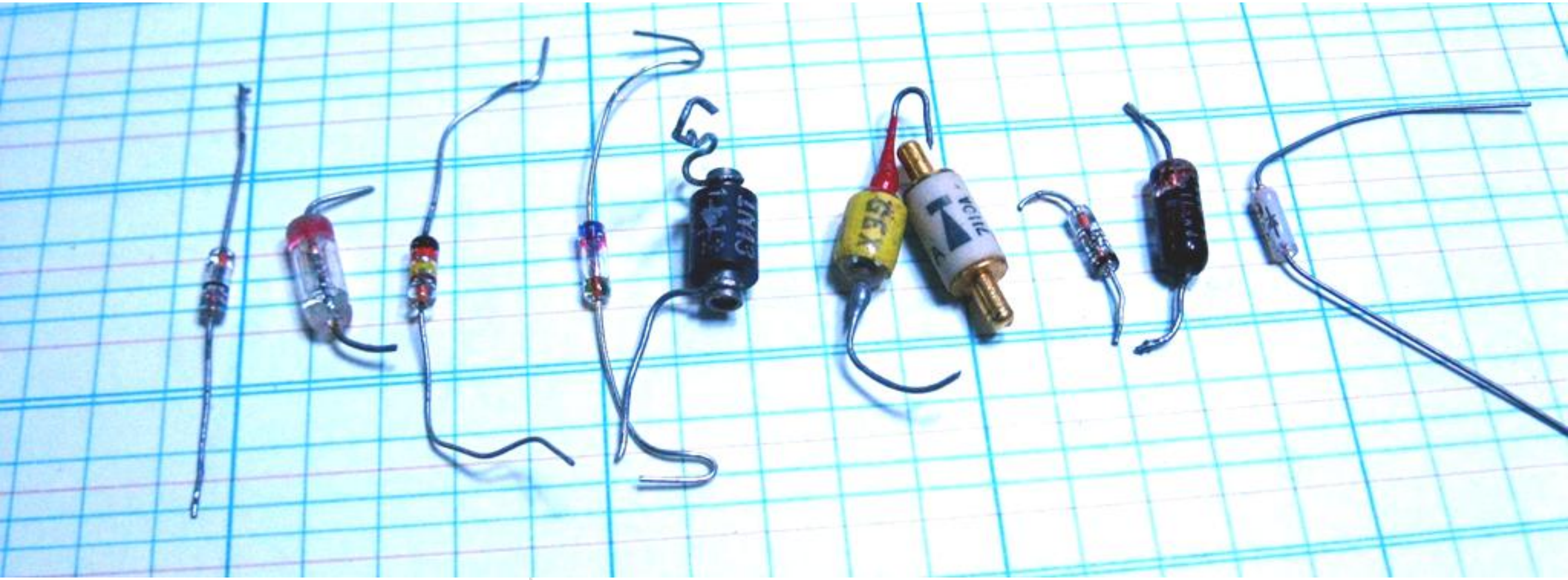


- In my experience, nothing beats a good 1N34A germanium diode. (Still widely available)
- Germanium is good because its barrier height (turn-on voltage) is lower than silicon, and a germanium diode is truly a point-contact diode (Schottky, not P-N diode), so has low charge storage (and therefore fast switching times).
- Specified with very low capacitance, less than 1.0pF.
- Main complaint about 1N34A diodes is that they tend to have high and highly variable leakage.
- Best solution is to try several, doing A B comparisons and select the best germanium diode in your drawer .

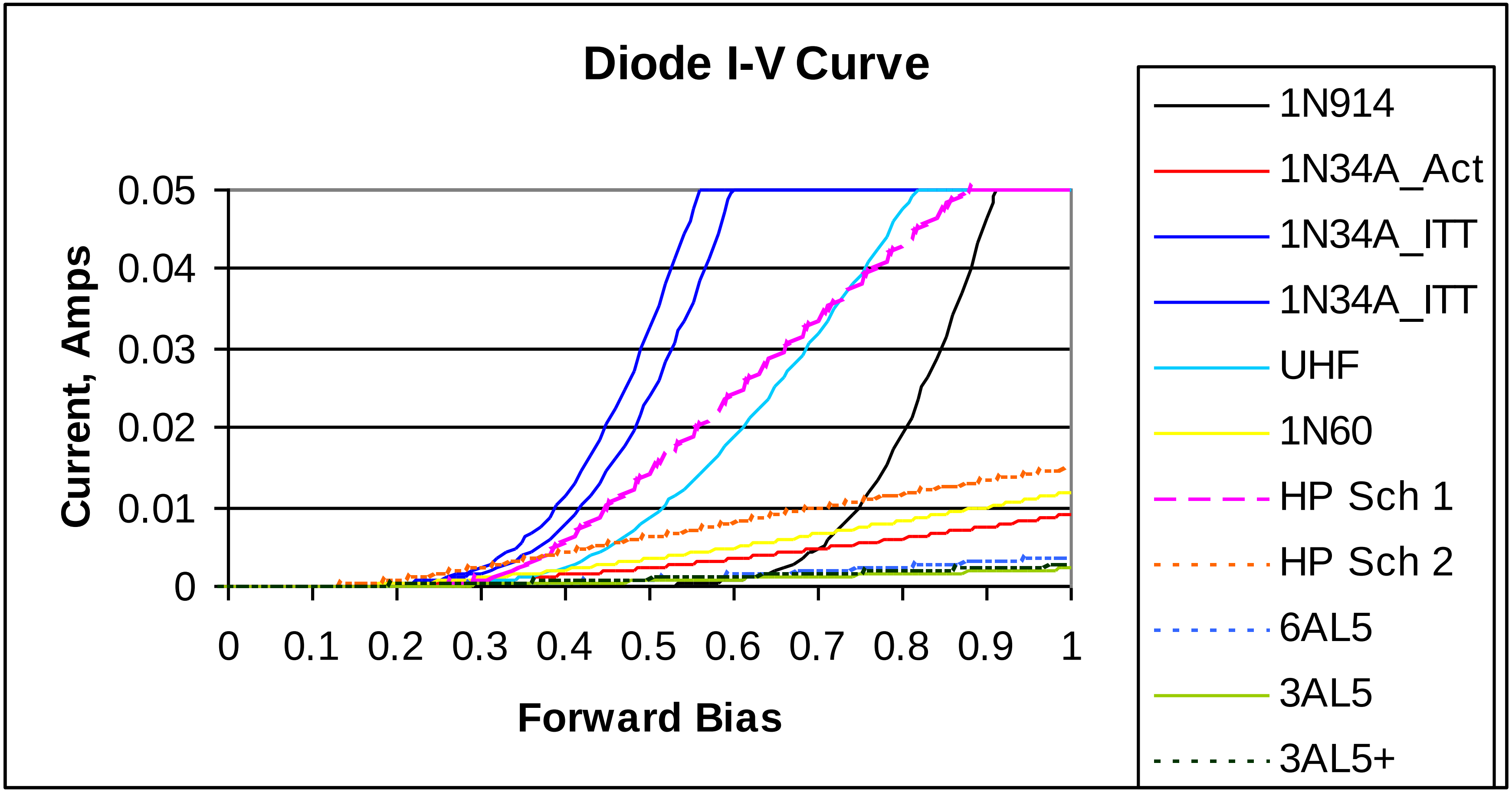
Detector Impedance

- Detectors are most efficient when driven with *high voltages*.
  - Detectors are "square law" devices (at low power), output voltage is proportional to square of input voltage.
- Since we have a fixed amount of input *power*, we need to increase voltage and decrease current applied to the detector (Power=Voltage x Current); in other words increase the detector *impedance*.
- At detector input: use a loose coupler.
- At detector output: use a 100kohm microphone transformer to match into the headphones.

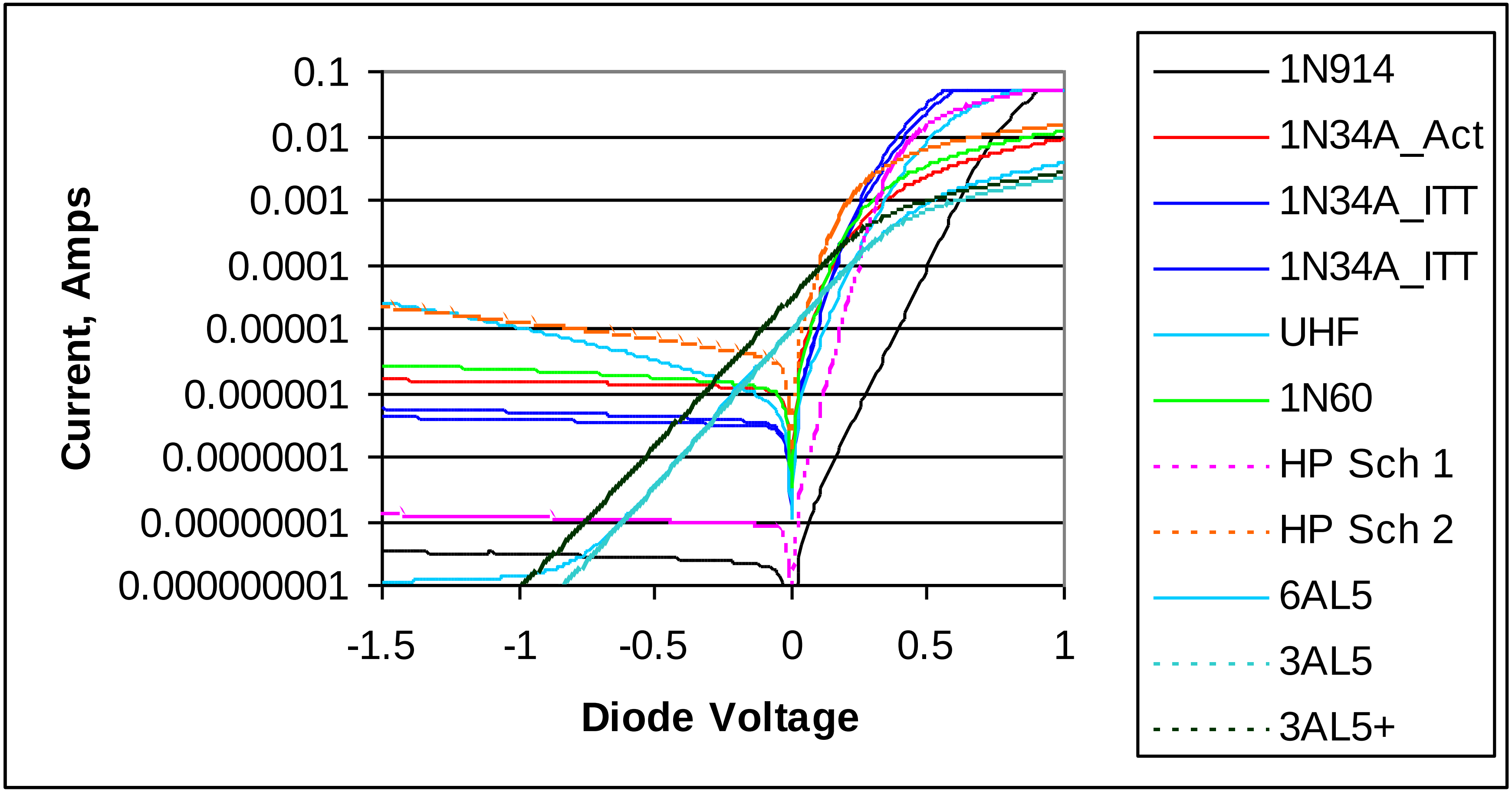
Germanium Diodes



Detectors: I-V Curves



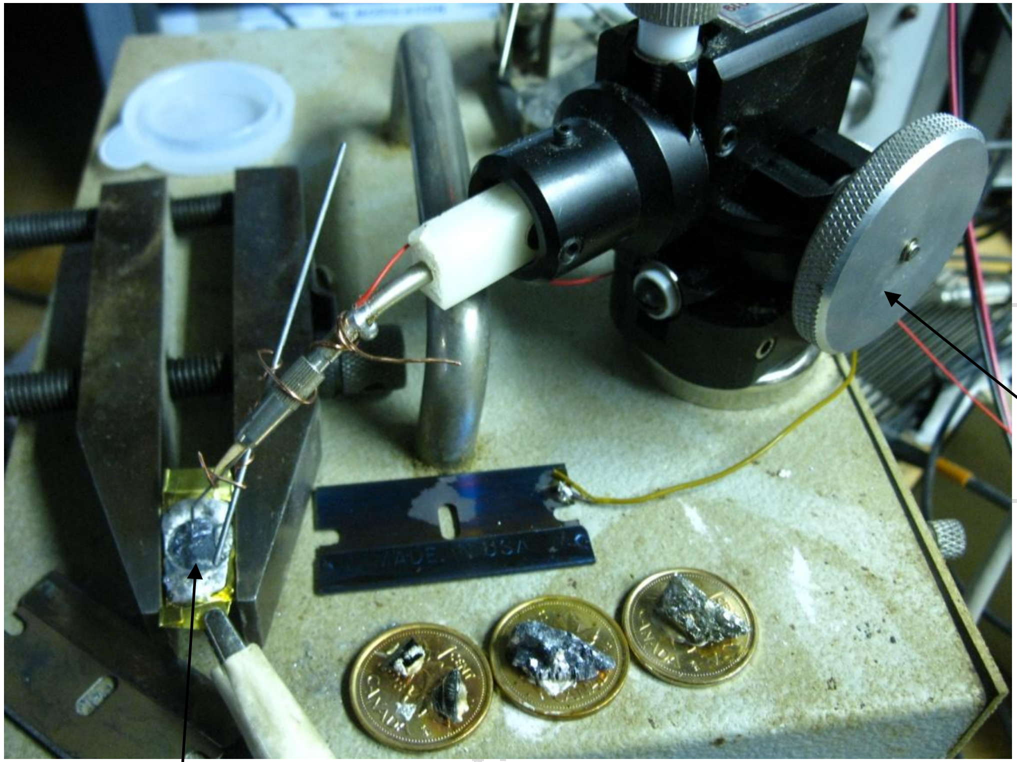
Detectors: I-V Curves



Mineral Detectors

Lead Sulfide, PbS (Galena), Iron Pyrite, Zincite, and other minerals have been used to make detectors (surprisingly good).

Galena Detector



X-Y-Z manipulator

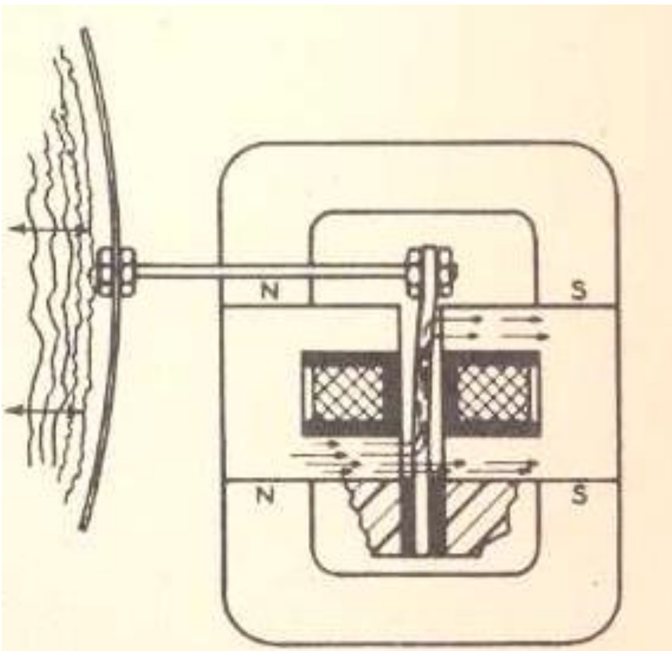
Galena mounted in solder

Audio Transducer

www.crystalradio.net

- Best transducers (headphones) for crystal radio operation are “Sound Powered” headphones or “Deck Talkers”.
- Developed in WWII for the navy to allow communications between the observers and gunners without the need for external power source.
- So sensitive that the pressure of the talkers voice in the microphone is sufficient to drive the headphones of the listener.

Audio Transducer



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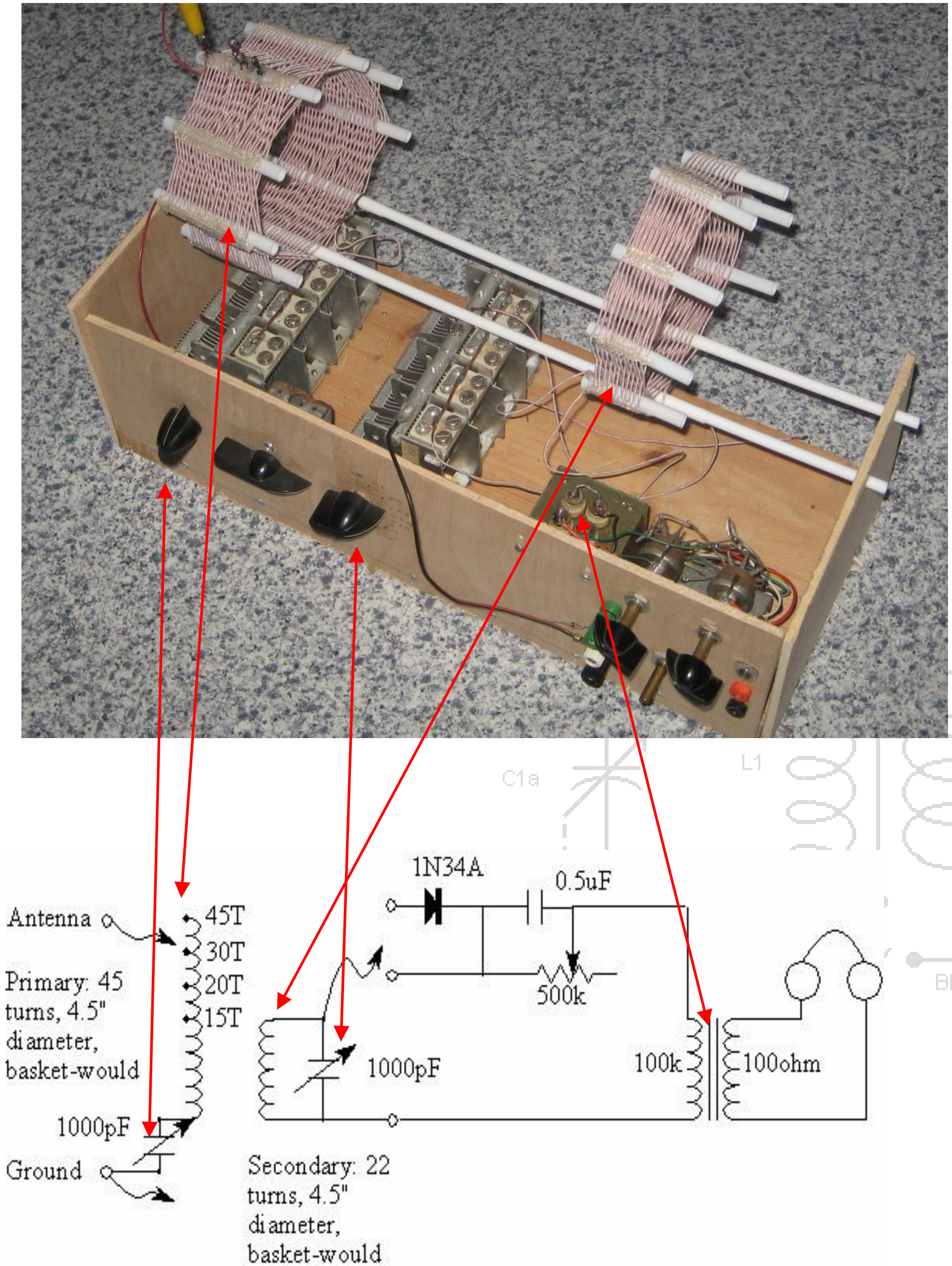
- An elaborate mechanism balanced armature system) give the sound powered headphones their sensitivity.
- Impedance typically around 1000 ohms, much too low for direct use in a crystal set. An impedance matching transformer is essential.
- Microphone transformers are excellent choices for matching the impedance of the diode to the headphones.

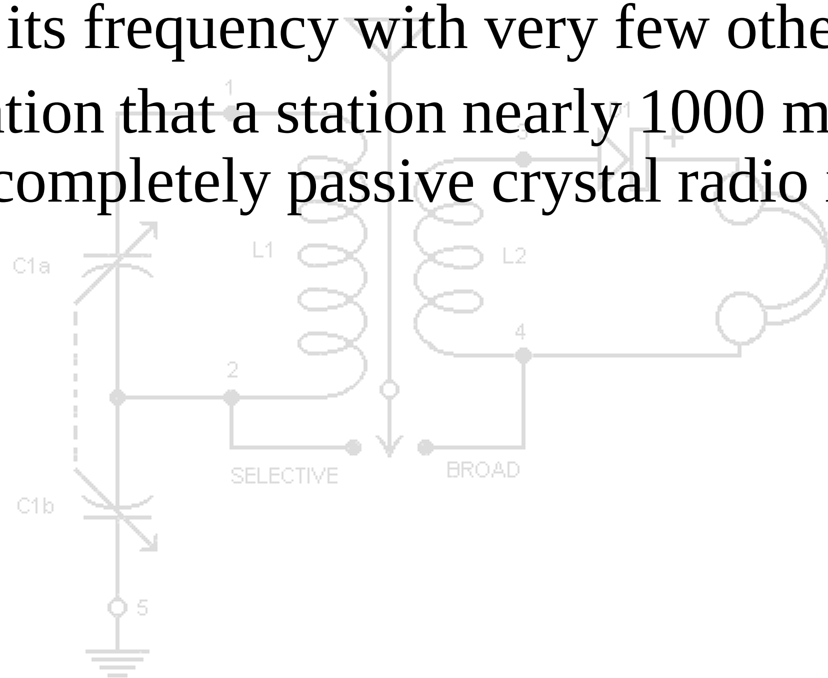
Final Results



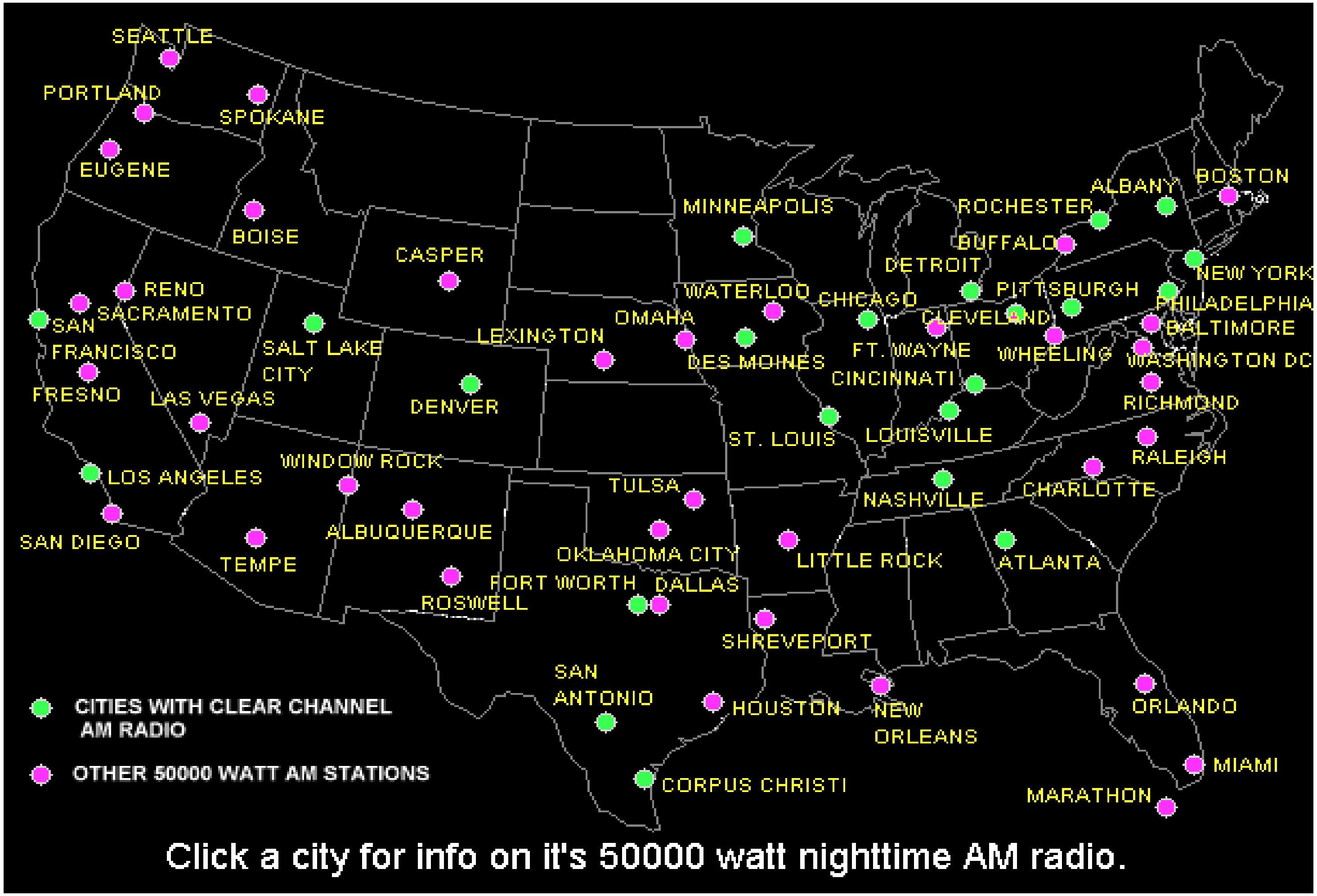
- Litz wire basket wound with taps for experimentation.
- Series antenna tuner above 650kHz. Below 650kHz, capacitor has to be placed in parallel with the inductor
- Ceramic insulated variable capacitors for maximum Q
- R-C allows DC to build up, reduces detector loading and reduces distortion on local stations.

Clear Channel Stations

- Most of the distant stations we receive are 50,000 Watt “clear channel” stations.
- A clear channel station is a high power American station that shares its frequency with very few other stations
- The realization that a station nearly 1000 miles away can be heard in a completely passive crystal radio is amazing



Clear Channel Stations

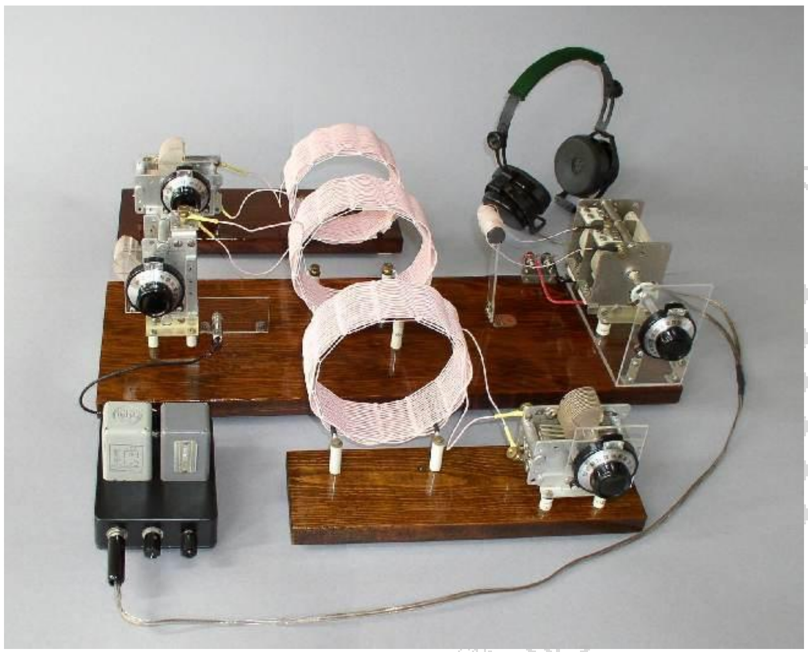


- http://www.fortunecity.com/tinpan/bluenote/706/namrp/amradio.htm#anchor3

Stations Logged

- 640 CFYI, Toronto
- 660 WFAN, New York City
- 680 CFTR, Toronto
- 690, Montreal
- 700 WLW, Cincinati
- 720 WGN, Chicago
- 740, Toronto
- 760 WJR, Detroit
- 770 WABC, New York City
- 780 WBBM, Chicago
- 800 CJAD, Montreal
- 810 WGY, Schenectady
- 840 WHAS, Louisville
- 880 WCBS, New York City
- 920 WHJJ, Providence
- 940 CINW, Montreal
- 990 The Team, Montreal
- 1000 WMVP, Chicago
- 1010 CFRB, Toronto
- 1020 KDKA Pittsburgh
- 1030 WBZ, Boston
- 1060 KYW, Philadelphia
- 1080 WTIC, Hartford
- 1500 WTOP Washington
- 1520 WWKB, Buffalo
- 1560 WQEW, New York Citiy

Top Performers



www.crystalradio.net

- Mike Tuggle of Hawaii is one of the top builders of crystal sets.
- His set, the Lyonodyne-17 has heard stations in Cuba from his home location in Hawaii!
- There are lots of web resources available. This presentation describes my efforts.

Conclusions

- Crystal sets appear to be simple, but attention must be paid to all the details.
- If you truly understand a crystal radio, you have a good foundation to RF engineering in general.

www.crystalradio.net

LOOP AERIALS
And ATUs

LOOP & FRAME AERIALS
and ANTENNA TUNING UNITS

LOOPS
A Loop or Frame aerial is a wonderful tool to assist long wave and medium wave reception and, indeed, absolutely essential for serious long distance reception (DX-ing). Fortunately a loop aerial is extremely easy and very cheap to construct, you may even have most of the parts required in your junk box. I offer a few pointers to the construction of loop aerials below.

ATUs
For good Short Wave reception long 'random wire' aerial really is required to dig those distant stations out of the ether. To effectively couple such an aerial to a radio a matching unit called an ATU (Antenna Tuning Unit) can be extremely helpful. An ATU is relatively straightforward to construct and uses simple parts that are quite easy to obtain.
> Go to the ATUs page for a few pointers.

LOOP AERIALS

A loop aerial is extremely helpful when trying to receive long distance stations, not only will it dramatically 'boost' the signal received compared to using a portable radio's internal ferrite rod aerial because a loop aerial is much bigger than a ferrite rod, but it also has two other very useful properties: **Directivity** and **Selectivity**. Directivity is very useful in that it can often be used to 'null out' an interfering station and selectivity is useful to overcome overloading of the radio's 'front end' as the loop will tune very sharply to the required frequency will rejecting all others.

When using a communications receiver a frame aerial might be more convenient than installing a 'long wire' antenna. Although a frame aerial might not collect as large a signal as a really long wire, the directional properties are very useful for nulling out interference from unwanted stations.

Construction

A loop can be made for Medium Wave and Long Wave and can be of almost any size you wish, although it must be small enough to fit in your listening room! The bigger the area of the loop the more signal it will collect, the portable loop described below is around 40 cm in diameter and is probably the smallest size worth considering to be effective and useful.

Traditionally loop aerials have been made on large frames about 1 meter square for use with communications receivers and is essentially just one long piece of thin 'hook-up' wire wound approximately 8 to10 times around a wooden (or other non metallic) frame. The frame can be somewhere between about 50cm square and 1m square - the dimensions are not especially critical

but some experimentation will be required to find the exact number of turns required for a particular size of frame so that the desired tuning range will be obtained. - As the size of the frame is increased the inductance of the windings will increase, therefore it may be found that slightly fewer turns will be needed for correct coverage. For example for the Medium Wave band a 1m square frame may only need - say - eight turns on the main winding compared with ten turns on a smaller frame.

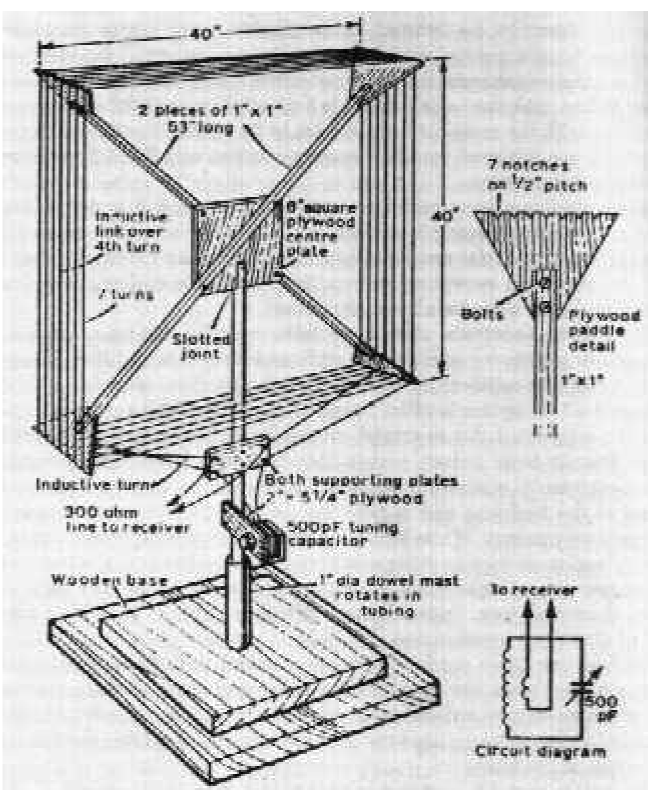
The bigger the area of the frame, the larger the signal pick-up will be.

The wire ends of this main winding are simply connected across pretty much any standard medium wave tuning capacitor with a value of something about 300pF or 500pF or similar. Again this is not especially critical, though like the number of turns of wire it will affect the tuning range. Therefore if a very low value capacitor is used - say 150pF or 200pF - then an additional turn or more on the main winding may be required to enable the lower frequencies to be tuned. Even with a 300pF tuning capacitor it will probably be necessary to include an additional fixed capacitor - connected in parallel with the tuning capacitor - that can be switched in and out of circuit. This will enable the tuned circuit to resonate at lower frequencies and is shown in the diagrams below.

470pF may be a good value to try for the fixed capacitor, but experimentation with different values may be necessary to suit the particular value of tuning capacitor and size of frame being used.

This loop of wire and tuning capacitor form a simple 'Tuned Circuit" which can be tuned across the Medium Wave band using the variable tuning capacitor.

MW and LW Frame Aerial



Constructional details

The illustration opposite was taken from a very old listening guide and shows the basic method of constructing a traditional style large frame aerial. It is 40 inches (100cm) square and made of wood with the loop windings wound over the four plywood 'paddles. I have tried this method and it works very well. Certainly the increased surface area really improves signal pick-up and is ideally suited to 'communications' receivers.

I have also experimented with different shapes, since 40 inches (100cm) can be a bit too wide for some small rooms. My favourite is taller than it is long and is hexagonal in shape being 150cm tall and 70cm wide.

For Medium Wave reception 9 turns are required for the main winding. A switched capacitor to extend the tuning range could also be included if the tuning range is found not to cover the whole of the band.

Coupling or Connecting To The Receiver:

When using a portable radio with a built in ferrite rod ("Loopstick") aerial, it could be quite easy to

A Long Wave Loop Aerial

place the radio inside the loop and therefore use Inductive Coupling between loop aerial and the radio's own aerial. Rotating the loop and radio together for best reception by making use of the aerial's directional properties.

However when using a communications receiver that has a dedicated aerial socket or antenna terminals then the frame aerial must be connected to the radio by a cable. Since a communications receiver will not, in most cases, have a ferrite rod / loopstick antenna, the frame aerial cannot be inductively coupled to the radio in the same way as for an ordinary portable radio:

Therefore a second loop of wire - the inductive coupling loop - is wound over the main winding: This is just one single turn of wire, the ends of which can form a 'fly-lead' that can be connected to the antenna terminals on the receiver. This single turn of wire is shown in blue in the diagrams a little further down this page.

Long Wave

For use for Long Wave reception approximately 30 turns will be needed. The exact number will be established by a little experimentation and adjustment. The photo on the left shows a Long Wave loop aerial. The windings are wound over the 'paddles' described above and consist of 31 turns plus the one coupling turn.

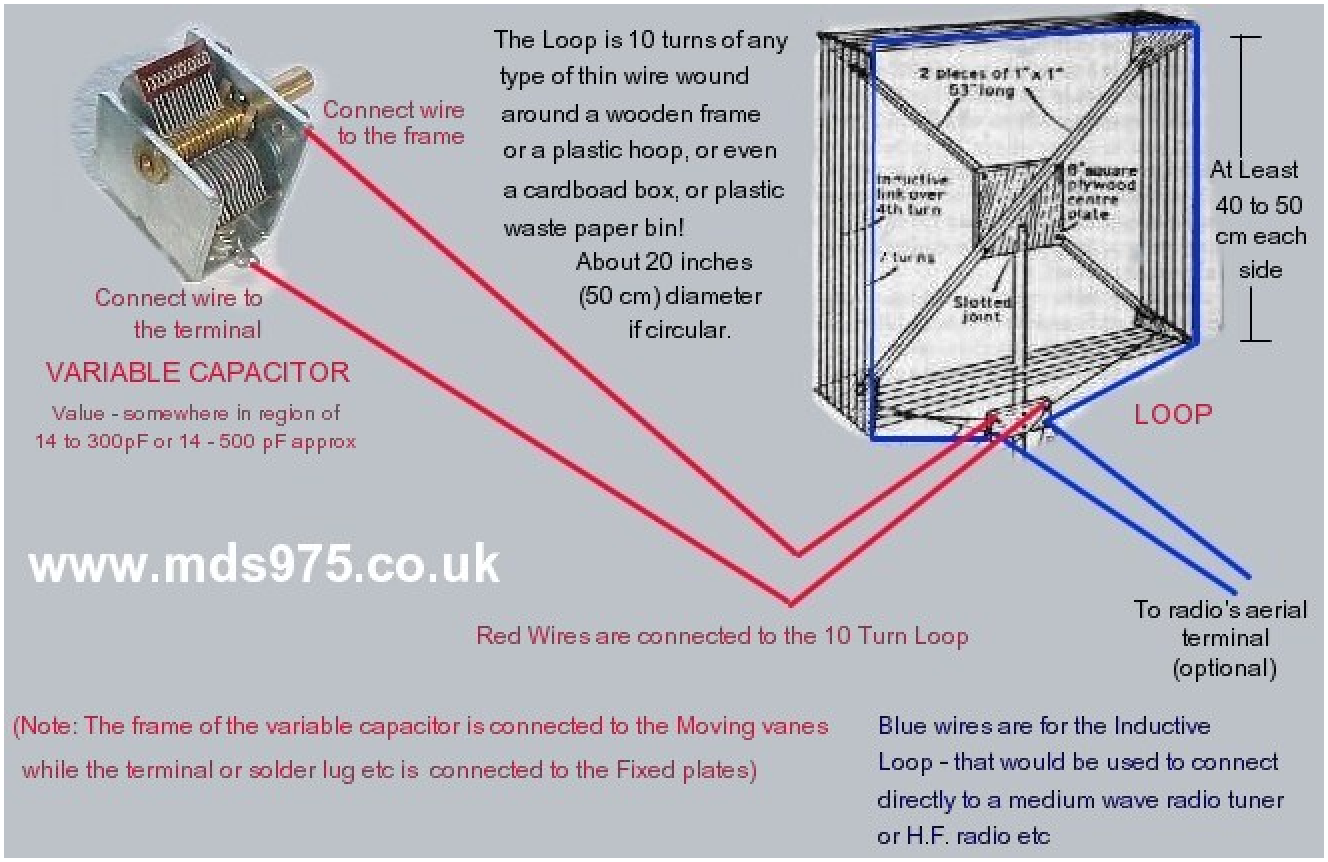
The frame is made from broom handles which are joined together using halving joints and a screw. The base is used for this aerial and a Medium Wave loop aerial and is made from an off-cut of kitchen worktop which is dense and heavy. A block is screwed to the base with a hole bored in it to suit the diameter of the 'broom handle' frames.

The tuning capacitor, switch and sockets are neatly housed in a plasic enclosure of the same type as the one used for the portable loop described above.

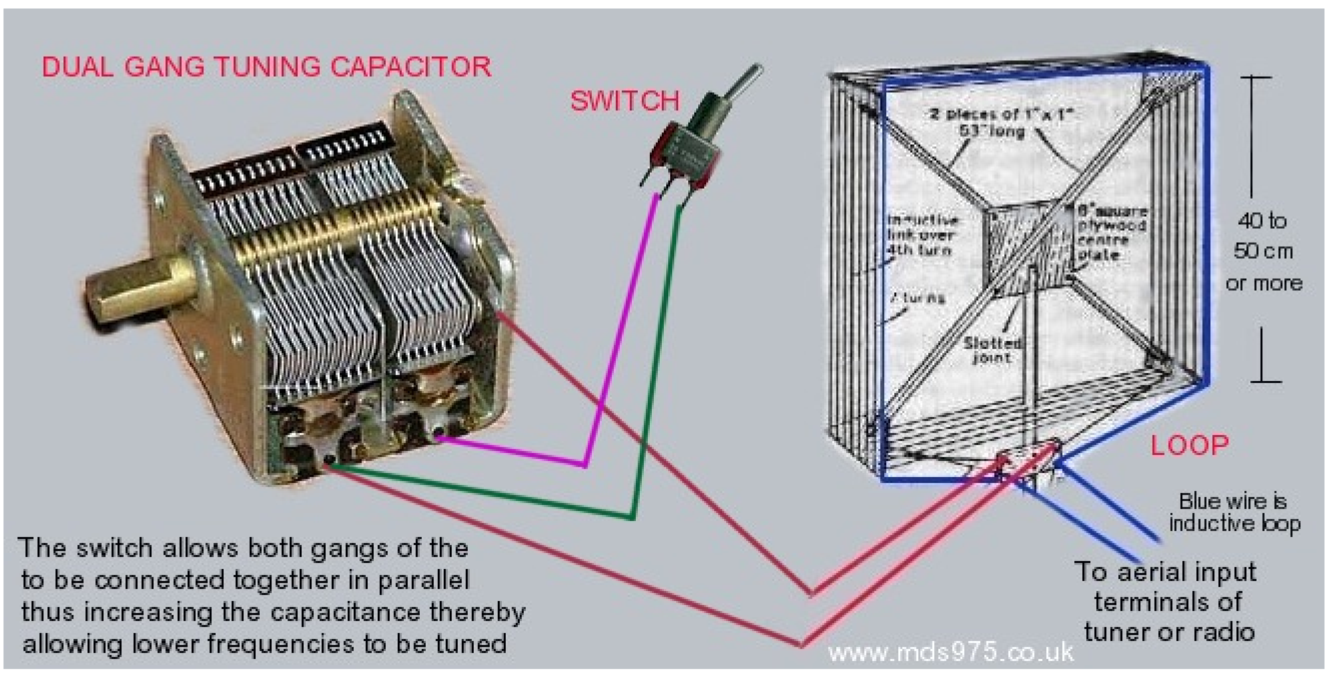
1 meter square is probably the largest size that would normally be considered practical. for a frame aerial that is used in the home, but even this may be too large in some domestic circumstances. This Long Wave loop is only 55cm wide and 150cm high and is more easily accommodated in a small 'box room'.

Some Helpful Wiring Diagrams:

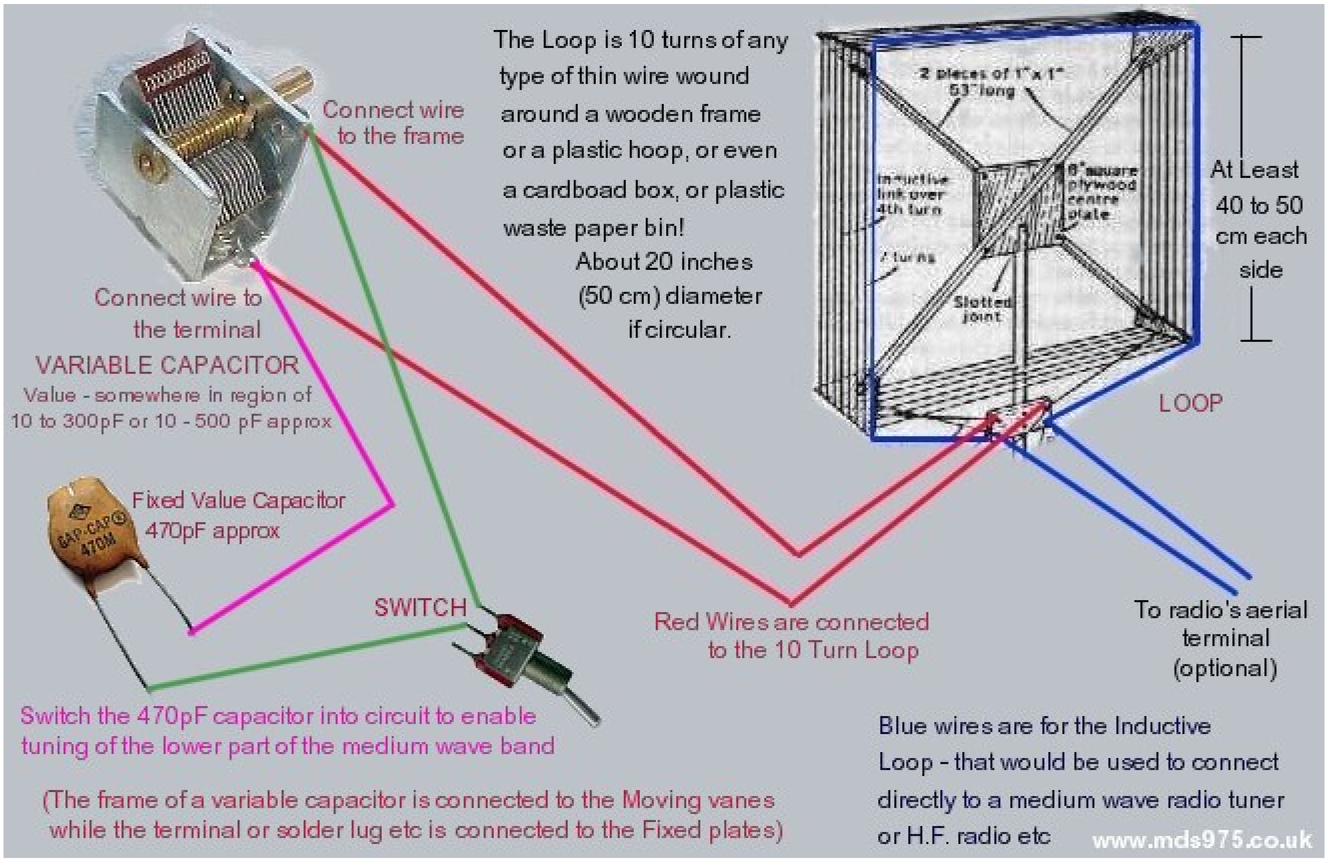
Applicable to all styles, shapes and sizes of loop aerial:



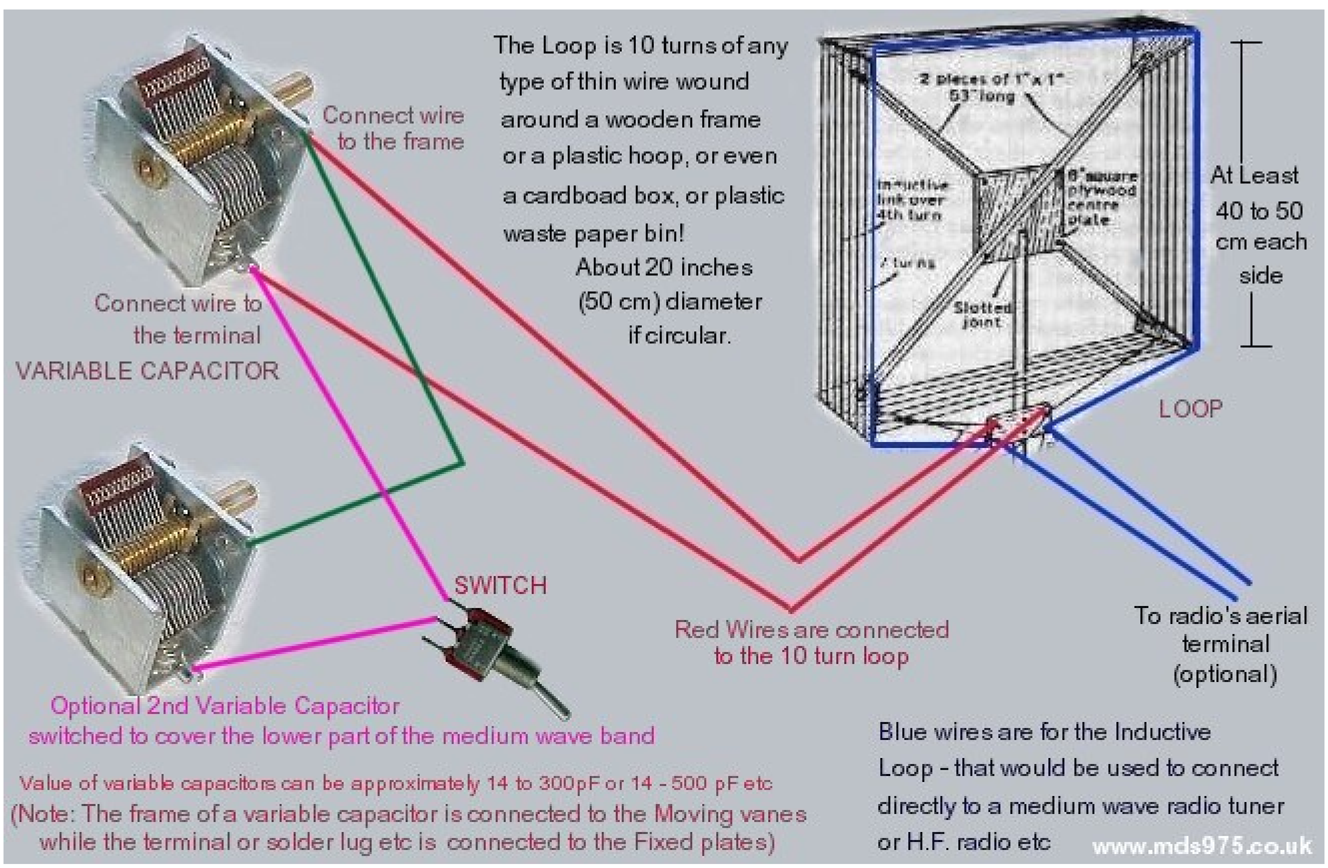
Basic Wiring of a Medium Wave Loop Aerial



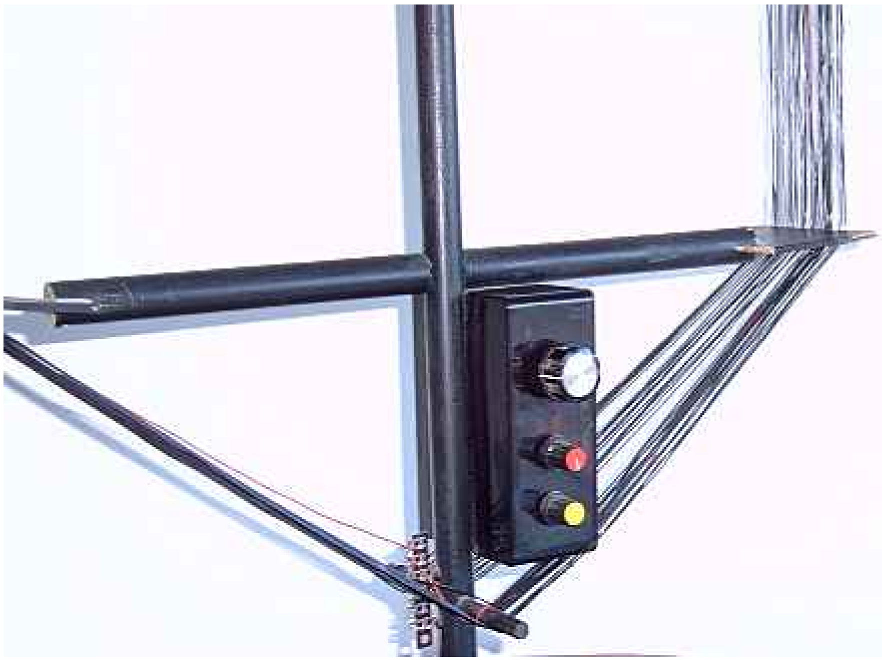
Using a dual gang tuning capacitor to tune to lower frequencies



Increasing the low frequency tuning ability by adding a switchable fixed 470pF capacitor



Increasing the low frequency tuning ability by adding an additional switchable tuning capacitor



Shown Above: A close up photo showing the 'control box' and the joint of the broom handles that for the frame. The loop windings which are first taken to a tag-strip and soldered in place before the wires are taken into the control box, this help keep the windings taught. The circuit for this loop is the same as for the portable loop above except for the addition of a variable 1k resistor across the coupled output to act as a simple attenuator.

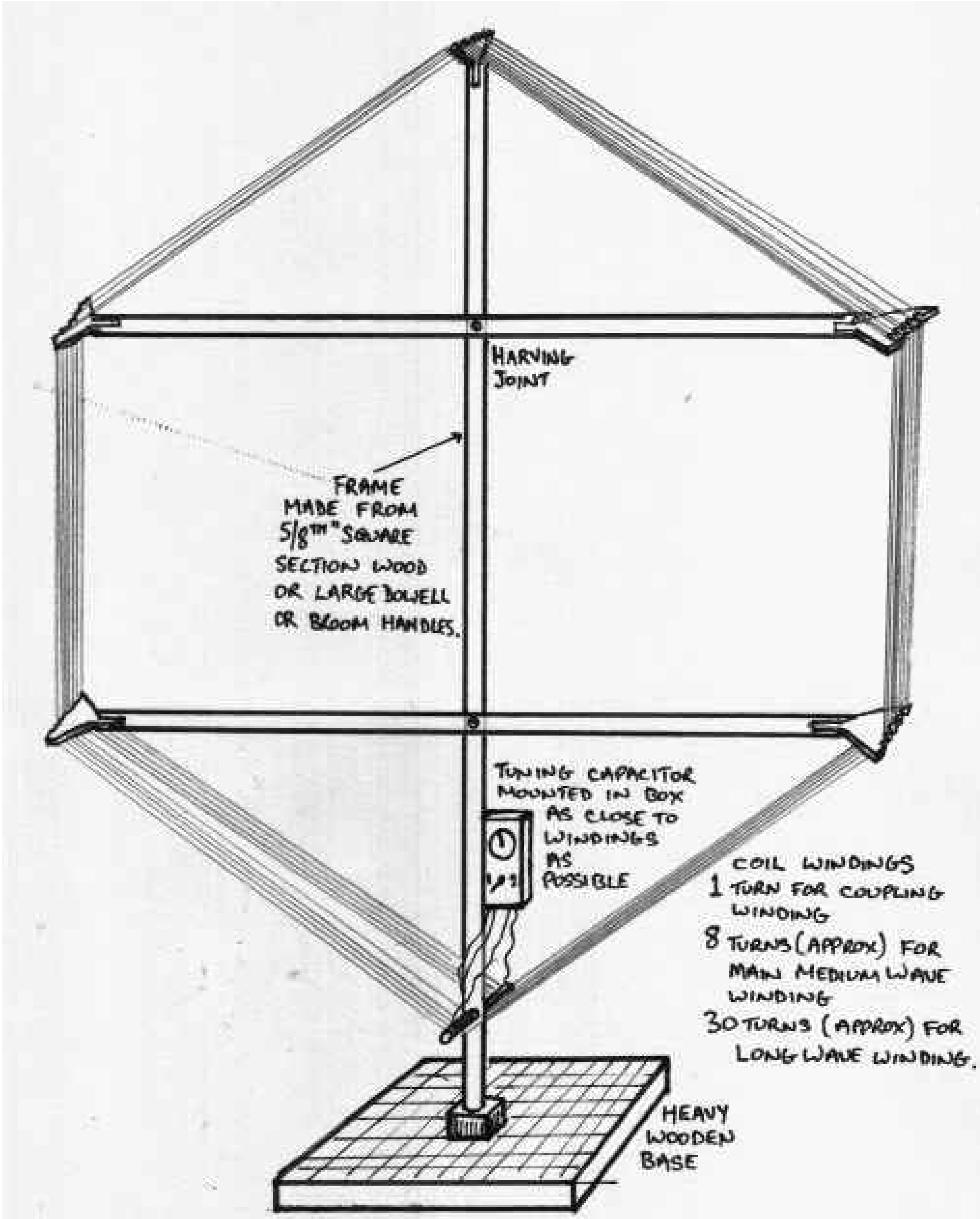


Diagram of Long Wave Loop

As shown above: For a size that might be more easily accommodated in a smaller listening room, a frame aerial can be taller than it is wide - for example between 120cm and 150cm tall and 50cm to 80cm wide.

Tuning and Operation

Find a very weak station that is almost inaudible. Couple the radio to the antenna and rotating the tuning capacitor on the frame aerial: As the resonance of the loop aerial approaches the frequency of the radio station the recovered audio will rapidly become louder and clearer until it reaches a peak. The peak of loudness will be at the exact point of resonance of the aerial - i.e. if tuned to a weak radio station on, say, 1566 Kilohertz when the audio is at its loudest the aerial will also be tuned (resonated) at 1566kHz.

The automatic gain control (a.g.c.) circuits of most radios can mask these peaking effects somewhat,

but it should still be quite obvious when the point of resonance is achieved.

Band Coverage

Two separate frame aerials will be needed to cover both Long Wave (150 to 280 kHz) and Medium Wave (510 to 1611 kHz).

With the medium wave aerial the band wave may possibly need to be covered in two parts by either having 2 tuning capacitors wired in parallel (depending on their value), or by having one tuning capacitor (of about 500pF) and a fixed capacitor that can be switched in to circuit (wired in parallel) to cover the lower part of the band.

To get the correct coverage the trick is to set the loops aerial's tuning capacitor to its minimum value (vanes open) and tune the receiver to the top of the medium wave band (1611 kHz in Europe and 1705 kHz in North America) then adjust the number of turns of wire wound around the frame until the top of the band can be tuned in and 'peaked up' by the aerial's tuning control. Since the may not be a broadcast station present it will be necessary to listen for a peak in the overall noise level.

Important: Use as many turns of wire on the loop that will still allow the top of the band to be tuned in. Don't remove a turn unless really necessary since the more turns of wire there are on the loop the better the pick up will be.

Once that is done check how far down the medium wave band the aerial will resonate.It may only tune down to 700kHz or 800 kHz for example. If that's the case then a fixed value capacitor will need to be added that can be switched into circuit - connected in parallel with the tuning capacitor. The value will vary depending upon what value tuning capacitor is being used, the size of the frame and the number of turns on the loop, but maybe somewhere between 200pF and 600pF (ish). With careful experimentation the exact value can be established that will allow a particular loop to tune down to 510 kHz - the lowest end of the medium wave band.

A Portable MW Loop Aerial

With smaller loops and a small portable radio with a built in ferrite rod ("Loopstick") aerial, it is very easy to place the radio inside the loop to obtain the best Inductive Coupling between loop aerial and the radio's own aerial. Rotating the loop and radio together for best reception by making use of the aerial's directional properties.

The Portable MW Loop Aerial, shown to the left, is much smaller than many traditional frame aerials at 40cm (17") diameter. It is designed for use with a portable radio. The radio is simply placed in the middle of the loop and the signals collected are transferred to the radio via its internal ferrite rod aerial.

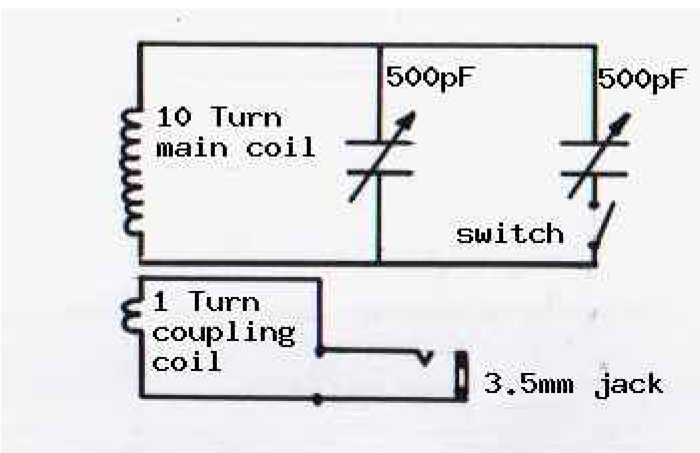
The circuit for a loop aerial could not be simpler: A continuous length of wire, such as 7/0.2mm 'hook-up' wire, is wound around the 40cm former to form a loop of approximately 10 turns*. The tuning capacitor is connected across the loop so that it can be adjusted to resonate at different

The portable loop in use, the portable radio is simply placed into the centre of the loop and the signals collected are inductively coupled to the internal ferrite rod antenna of the radio

frequencies.

(*about 40 to 50 turns for Long Wave).

If it is required to connect the loop to a radio via its aerial input terminal then a second winding of just 1 turn of wire is wound over the main 10 turn winding. This secondary winding acts as an inductive coupling coil - this is then connected to a suitable socket so that a cable ('fly lead') can be run from the loop aerial to the radio receiver's antenna jack or terminals.



The circuit diagram of the loop showing the 10 turn main winding (100uH) and the tuning capacitor, together with a second capacitor that can be switched into circuit to provide tuning of the lower frequencies of the medium wave band. The second 1 turn coupling winding allows direct connection to the aerial terminals of a receiver.

For Long Wave reception about 40 to 50 turns may be required.

The circuit diagram on the left shows the main loop winding of ten turns (100uH) and the variable capacitor which tunes the loop aerial to the required frequency. Ideally the tuning capacitor should have a value of 700pF to cover the whole of the medium wave band. However standard 500pF tuning capacitors seem to be more widely available and will generally tune the medium wave band from around 700 kHz to 1600 kHz with a 10 turn winding.

To Tune the lower portion of the band a second capacitor can be switched into the circuit to provide the increased capacity required. The second capacitor can be in the form of a variable trimmer that can be pre-set to the required value, usually around 200pF. The second capacitor *could* be another tuning capacitor (as shown in the diagram), but that could be rather expensive. Alternatively a fixed capacitor could be used, the best value determined after a little experimentation.

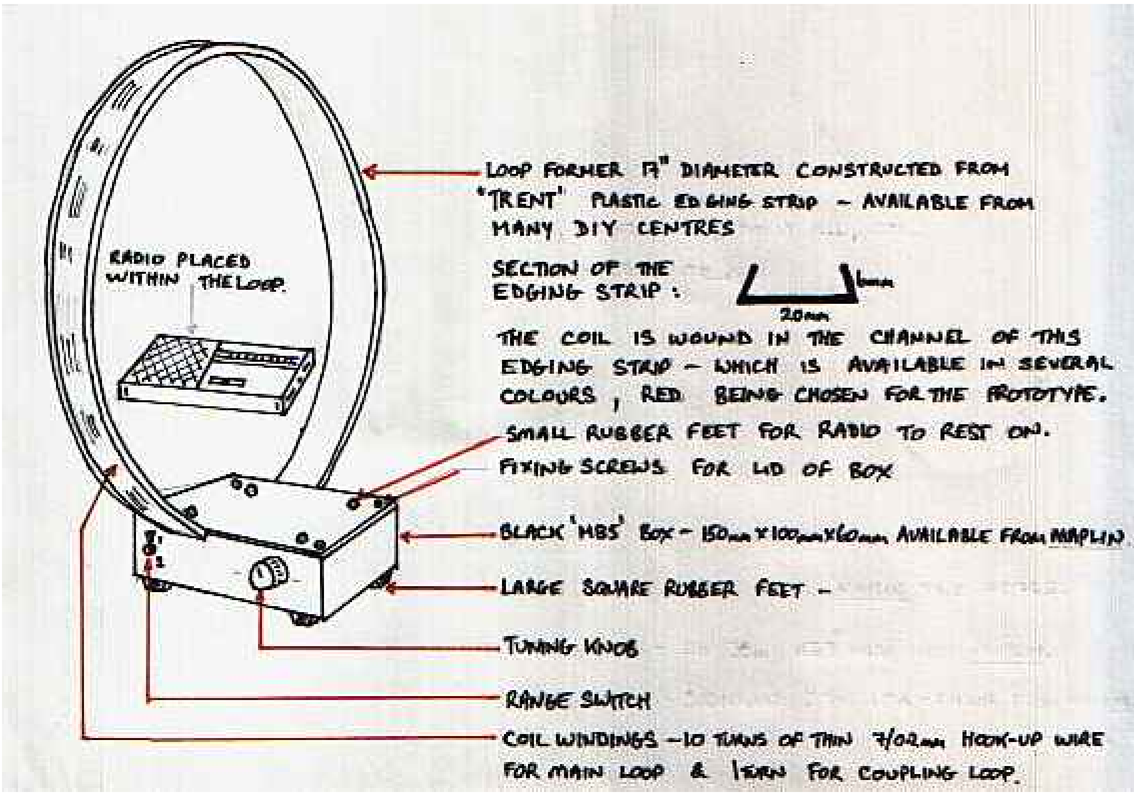
The second coupling winding is of one turn and allows the aerial to be directly connected to any radio with antenna terminals or and aerial socket.

Scanned in below are my notes for the construction of the portable loop. The former of the loop was made out of 'Trent' plastic edge strip that was available from my local DIY store. This edging is about 20mm wide with a 6mm channel, though any similar edging or plastic product such as curtain

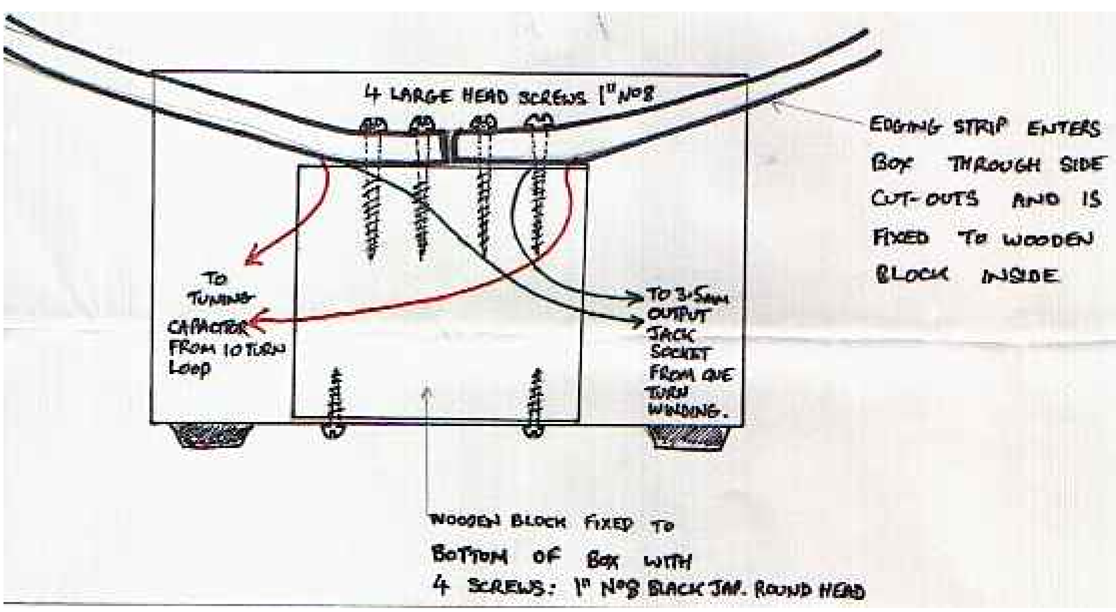
track, perhaps, could be used. The strip is bent into a circle of 40 cm in diameter with the channel on the outerside and fastened to a wooden block with some large head screws. The 10 turns of 7/0.2mm hook up wire are carefully wound side by side around the former and connected to the tuning capacitor. I used red strip and blue wire to be colourful.

The single turn coupling winding is wound next to the main winding and connected to the output socket. I simply used a 3.5mm jack socket as this is the same as on a Sony portable radio, though any coaxial socket could be used such as Belling Lee or PL259 etc.

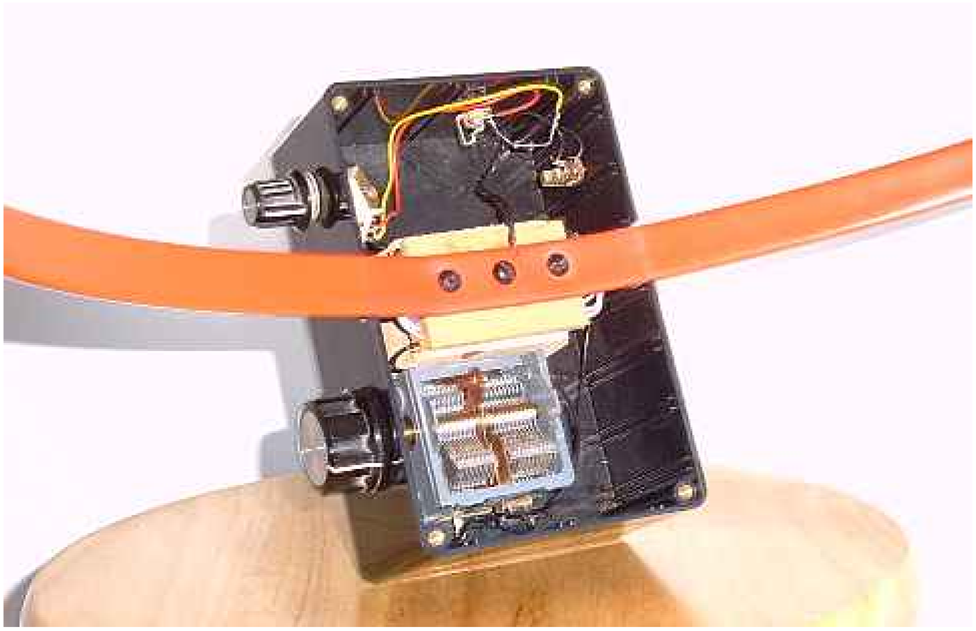
The loop and wooden block are fixed into a suitable plastic box of about 150mm x 100mm x 60mm, the wooden block and heavy tuning capacitor adding weight to aid stability. A suitable box would be BOX034 from [Bowood Electronics](#).



Drawing showing the external appearance of the Portable Loop Aerial

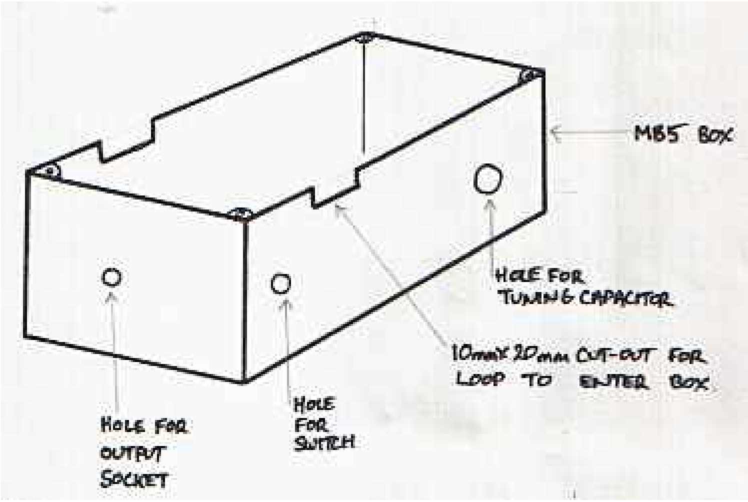


Drawing showing how the loop is fixed to a wooden block and secured into the enclosure

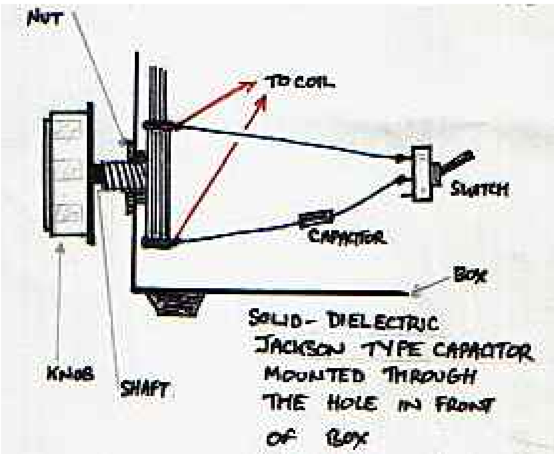


Internal photo of loop aerial showing air-spaced Tuning Capacitor (bottom left), Range Switch (top left), Output Socket (top), Wooden Block to which the loop former is attached (centre).

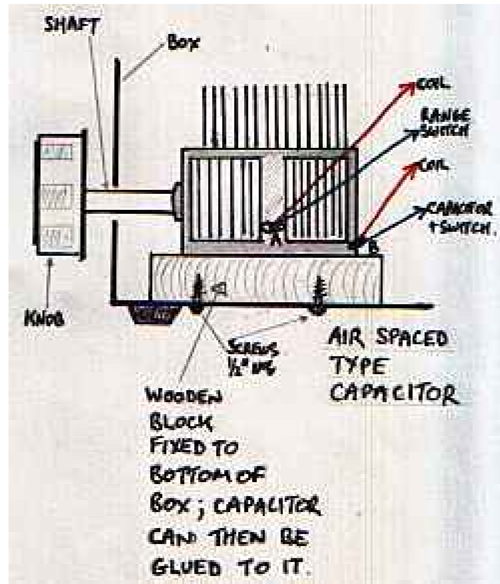
[Note the 3.5mm jack socket on the back panel (top right), this is for a crystal earphone as this loop is also a portable crystal set - see below]



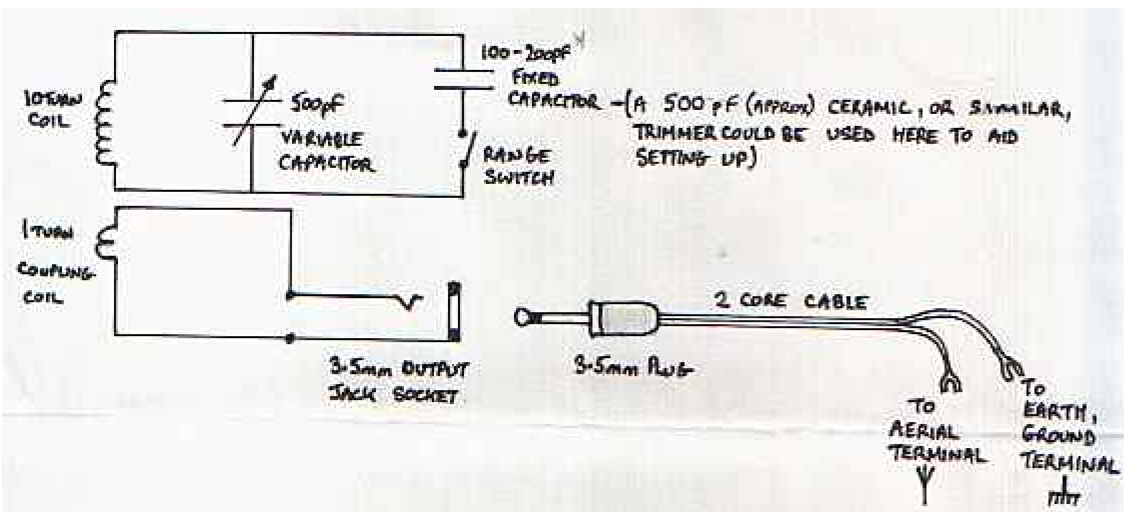
A suitable box with cut-outs to accommodate the entry of the loop into the box and holes for tuning capacitor, switch and output socket.



A solid Dielectric Jackson type tuning capacitor can simply be mounted through the front of the box and held in place with the brass nut.

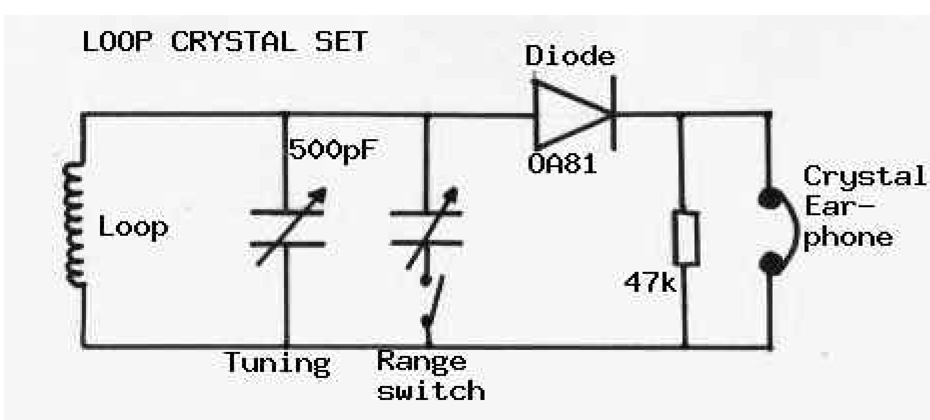


A traditional air-spaced tuning capacitor can be glued to a wooden block using Araldite which is then screwed to the bottom of the box.



Connecting a loop to a radio receiver or Hi-Fi tuner

A Crystal Set Loop!



Crystal Set Loop!

The circuit diagram above is an interesting modification to the loop aerial, and can be made to any loop aerial. With the addition of a germanium diode (not silicon) such as an OA81, OA91 or OA47, a 47k ohm resistor and a crystal earphone, the loop aerial becomes a portable crystal set which is quite effective given sufficient signal strength at your locality.

If signal strength is low then a long wire aerial could be connected to the crystal set and used in a more standard crystal set configuration. Such a long wire aerial could be coupled to the tuned circuit via a small trimmer capacitor of, say, 100pF. The capacitor would be connected to the top of the tuned circuit ("hot" side) at the junction of the main loop, tuning capacitor and diode. Alternatively the aerial could be connected by inductive coupling and would be acheived by adding a second winding around the loop consisting of, for example, one, two or three turns of wire: One end of this wire would be connected to the long wire aerial and the other end of the loop to the 'earthy' side of the tuned circuit (junction of main loop, tuning capacitor, 47k resistor and earphone in the above diagram.)

In Use

The photo on the left shows the finished Portable Medium Wave Loop in use, in this case merely placing the radio inside the loop will obtain much improved reception!

The loop is tuned to the frequency of the required radio station with the tuning knob which will really peak up the reception.

Rotating the loop will maximise the signal strength &/or minimise co-channel or adjacent channel interference for clearer reception.

Using this loop I can hear distant local stations that would otherwise be completely impossible to receive and it helps improve reception on all other weak stations. It's a nice little project that produces a really useful listening aid.

Once you've built this little beauty you may want to try something a larger frame aerial design shown near the top of this page.

The Portable Loop in use!

LOOPS FOR HIGHER FREQUENCIES

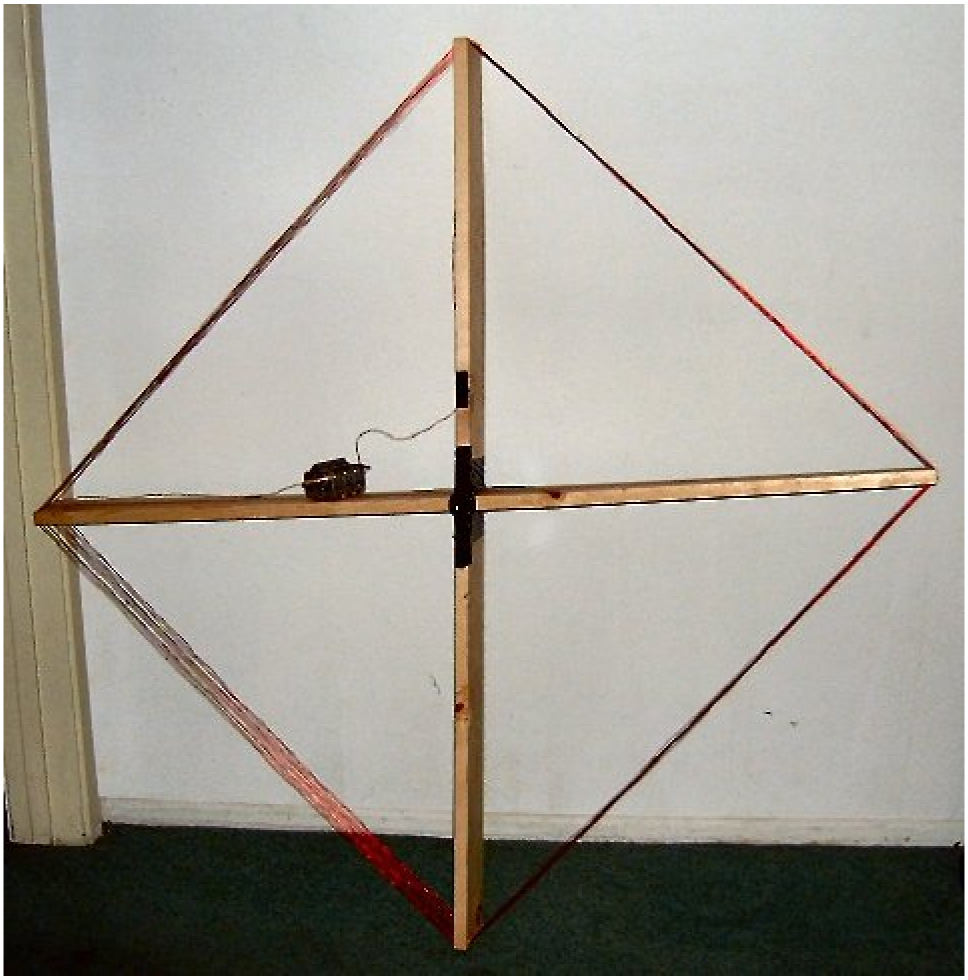
I have done a little experimentation with loops above 1.8 MHz, but not too much. My observations are thus:

It will take a little experimentation with the number of windings on the loop to get the required frequency coverage. The actual number depends on the size of the frame that you are using. To be able to resonate these higher frequencies the loop aerial requires fewer turns than the standard medium wave loop. Try removing 2 or 3 turns of winding from a medium wave loop and see where that gets you: Then subtract one turn at a time until the desired frequency range is achieved. Ideally the starting point of tuning at the lower end of the range should be around 1.8 MHz with the tuning range going up to about 3 MHz. This should cover some interesting transmissions including the "Top Band" of the Amateur Radio ('HAM') bands.

The coupling loop remains at one single turn whatever frequency range you are receiving.

It is important to note, however, that the fewer turns that the loop has (i.e. in order to tune to these higher frequencies) the less signal will actually be picked up - in my experience this reduced signal pick up has been quite noticeable! I found that for acceptable pick-up the frame needed to be at least 1m square. Smaller loops just don't present enough signal. It is for this reason that loops designed for long wave reception will necessarily have many more turns than a medium wave loop and will therefore be much more effective at collecting signals.

A loop for the higher frequencies above the medium wave band could be useful for direction finding and particularly for reducing co-channel interference (assuming the interfering station is at about 90 degrees to the required station), but for chasing weak signals a long random wire, possibly with an ATU, will be much better from my observations. An interesting experiment none-the-less.



Above: Photo of a frame aerial sent in by an MDS975 reader
- A very fine example!

AN INCONSPICUOUS LOOP AERIAL

An Interesting Loop Aerial Idea by Alberto San Juan who writes:

I like very much your web page (radio section), being very helpful to me. I also have a Lowe HF-150 and have installed my loop antenna around the small chest of drawers next to my desk, as you can see from the photograph below.

This method of construction has many advantages:

No big frames on your table.
Strong support, so it never falls over.
Gives you extra space.
Easy to move and rotate, it also has 4 wheels!
Easy to clean.
Easy and quick to hide under the desk/table.
You can place your radio on top of the aerial windings, or connect to receiver via cable.

Alberto San Juan's Loop Aerial design

So there you are - LOOP and FRAME AERIALS - cheap and very easy to make! The portable loop certainly looks the part, being very neat and tidy. The larger frame aerials are by their very nature more obtrusive, but can be even more effective at collecting radio wave energy due to their extra size. If construction is kept neat and tidy with the rough edges rounded off and the controls housed in a neat box a big loop need not be a major eye-sore.

Good Luck with YOUR loop aerial and happy LW and MW DX-ing!

Next I'll take a look at Antenna Tuning Units which will help match your long random wire aerial to your radio. ATU's, as they are known, will help with Short Wave reception as well as Long and Medium Wave too. ATU's Aerial Tuning Units

QUESTIONS ABOUT AERIALS

Hi Mike, I like to listen to the George Noory programme Coast To Coast AM (I miss Art Bell) on WFLA 970KHz AM. The problem is, when I do copy the station, it's always oscillating in and out and/or mixing with some tropical station (I'm in South Florida US).

I tried an external loop with fewer turns and no capacitor and just got similar results as a long wire (except when I turned the loop to attenuate both stations simultaneously). My DX'ing SWL longwire just picks up the QRM even with a selective Hallicrafter's Sky Champion. I was considering building and aiming a beverage antenna of hundreds of feet with a terminating resistor just to try to isolate this station.

Upon building your 40 cm loop with 10 turns and a 400 pF air cap, I now make the station resonate so well that it successfully overpowers the interference and takes charge when aimed and tuned. I only regret making the housing out of cardboard. The loop is that orange plastic race track that Hotwheels or Matchbox cars use from the 70's (it's that old, too).

I can't believe I'm listening to near-perfect "Coast to Coast" exoscience and UFO's etc. real time over the air. Ham Art Bell who started the show would be proud.

And I can add a switched 200 or so mica cap for the lower AM & take this with me to play with on the road (my radio to use with this is one of those Sangean, Tecsun, or Crane-like radios but sold by Radio Shack in their death throws and it just loves the loop). Can't wait to try top band. I wonder if I would ever pick up any long wave here with a LW loop? I was going to try the long-wire and switch the ground/cap configuration on my L-Match to effectively lengthen it, but darn the loop might work better.

Cheers and thanks again!

Jeff Burris
W4VEY
Tampa FL USA
(February 2016)

Hi Jeff,

Great to hear from you! I have listened to Coast To Coast with George Noory on past visits to Canada and enjoyed the programme very much too!

I am glad that you built the loop antenna and find it so useful and effective! I use mine regularly.

There is an AM station that I like to listen to - Manx Radio on the Isle Of Man. Unusually for a UK station, their transmitter has a 'figure of eight' radiation pattern. About 20 kW e.m.r.p. to the north-east and south-west, but only about 200 watts e.m.r.p. to the north-west and south-east - in my

direction. The loop really helps bring it in at night!

Not sure if you'll receive European long wave in FL, but I think it's been done. You'll need a big aerial, so perhaps the larger 150cm loop could work for you!

I want to make the most of this AM reception while I can since it is quite likely that many, if not most, AM transmitters in the UK will close by 2018 to 2020. BBC Radio Four on long wave is quite likely to close in 2020 and the largest AM 'network' in the UK (BBC Radio 5) may close by 2023. All these radio stations are already simulcast on DAB Digital Radio in many parts of the UK, with many listeners already choosing that method of listening. Some AM transmitters may carry on for a while after 2023 to cover areas that are difficult to reach with VHF radio (DAB digital radio is on VHF in the UK).

I love those big powerhouse (50kW) north American AM radio stations! They often have complex transmitter systems, with multiple mast phased arrays so that the radiation pattern can be extremely directional, with different day and night patterns and powers.

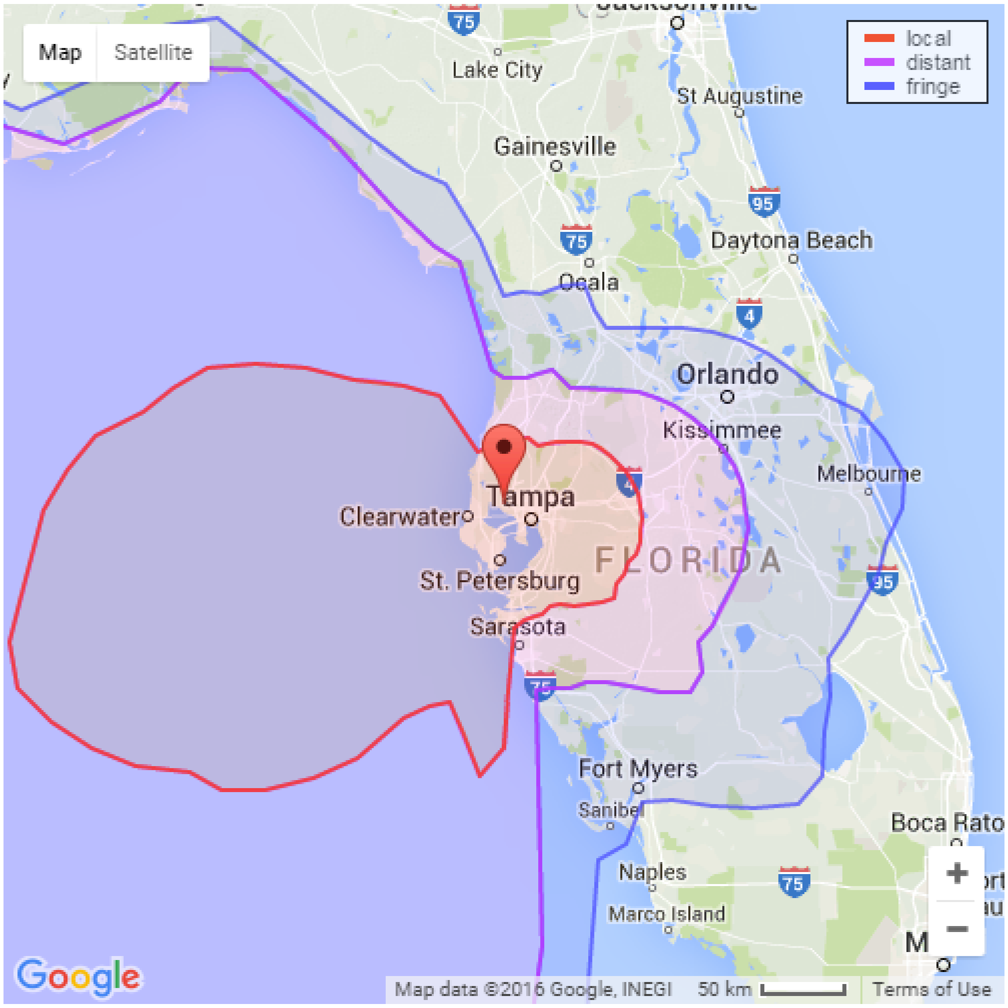
Often the night time power is a fraction of the day time power, and often more directional too, so that interference to other, more distant stations is limited. This can, of course, considerably weaken the reception to some of the station's more local listeners - possibly as you have found, particularly with interference coming in from foreign stations, causing co channel interference and fading.

WFLA 970 has five towers. I can only see three of them in the Google Maps screen shot below.

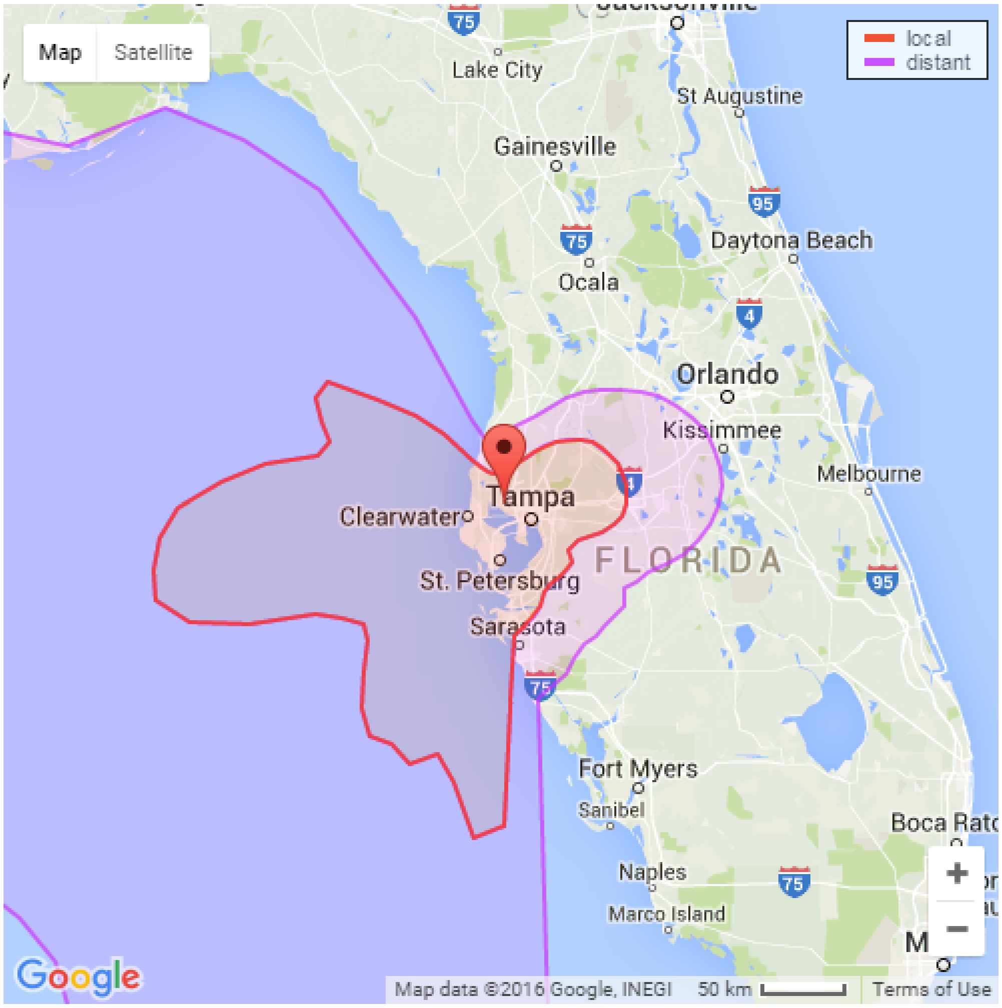
Four towers are used during the day to produce a directional pattern with a maximum power of 25kW.

Five towers are used at night to produce a more restricted coverage area, with a maximum power of 11kW. See maps below.

WFLA 970KHz AM transmitter site - only three of the five towers can be seen



WFLA 970KHz AM daytime coverage
http://radio-locator.com/info/WFLA-AM



WFLA 970KHz AM night time coverage
http://radio-locator.com/info/WFLA-AM

73 for now!! Happy listening and DXing!
Mike.
--

Hi Mike, I am in outback Queensland Australia, quite remote, so radio is very important to us out here. My use for my antenna will be to pull in distant AM broadcasts from within Queensland (200 to 500 kilometres away) and just very occasionally from interstate in outback areas of Australia. Mostly the signal may not be reflected, just very weak due to distance. Hope you understand my dilemma.

I have constructed a square loop frame with 750 mm sides (diameter) with two 320pf air gap tuning gangs. It tunes stations relatively well. My question relates to the wire length for the primary winding. I took some suggestions regarding length calculations for aerials and found most way too long for the gangs to be able to tune. I removed wraps one at a time as you suggest until I could get the higher frequencies to 'peak'. That is all good, but the result is that I now have only six (6) turns of wire in the primary. Only 18 metres. Since a full wave is about 300 metres, I feel there ought to be at least a quarter wave of wire in the primary, 75 metres. Is there any use in increasing the length of the primary coil to 75 metres? If so how can that be done?

Your advice will be enormously appreciated. Yours faithfully, Geoff Douglas. (February 2015)

Hi Geoff,

Thanks for your email.

I found the medium wave loop antenna to be an extremely rewarding project. I am sure that you will find it very useful too.

With regard to your question concerning wire length: The length of the wire does not really have quite the same relationship to wavelength that you might expect if you were dealing with more familiar receiving (and transmitting) aerials.

The aerials that many radio enthusiasts may well be familiar with are the Half Wave Dipole, the Quarter Wave Vertical Monopole or Full Wave Loop, for example.

The Half Wave Dipole is fed at the centre and consists of two quarter wave 'arms' either side of that central feedpoint. Such an antenna is often seen installed horizontally, so its form will look like a T - the vertical feeder cable feeding the two 1/4 wave 'arms'. The total length of the antenna is therefore half a wavelength long. So for a medium wave frequency of (for example) 720 kHz (416 metres) the aerial would be (approx*) 208 metres long.

The Quarter Wave Vertical Monopole is simply one half of a Dipole, fed against ground. So it would be (approx*) 104 metres high. The ground may be a network of radial wires and earth rods. Sometimes the vertical section may be 'loaded' to shorten it, thus reducing its efficiency. Alternatively, for reception, it may be installed as an Inverted L form: Made out of wire, the vertical section would be supported on a non metallic vertical pole as high as practicable, with the remainder of the aerial wire run out horizontally to be supported at its far end by another supporting pole, building or object.

The Full Wave Loop is, as its name suggests, is a loop of wire that is one full wavelength long at its design frequency, in this case (approx*) 416 meters long. It might be supported as high as possible above the ground on suitable poles or towers, as a horizontal circle or more often a square. The feedpoint will be a some point on its circumference.

The medium wave frame aerial is slightly different. Certainly, for a given size of former (frame) a longer length of wire will be needed for longer wavelengths. However, the loop forms a tuned circuit with the capacitor. The frequency (wavelength) that the loop will be most sensitive to is determined by the capacitance of the variable capacitor and the inductance of the loop's aerial winding: The more turns of wire on the inductor, the lower the frequency that will be attained. Also, the larger the inductor, the lower the frequency will be covered - so for a given frequency, the larger the frame the fewer number of turns will be needed.

Similarly, the larger the capacitance, the lower the frequency.

It's worth noting that the larger the frame, the larger the area, and hence the greater the signal pick-up - which is a useful consideration when trying to receive weak and distant stations. 1 metre square frames are quite popular.

You'll see, therefore, that it's not quite as simple as a quarter wavelength of wire is needed for a given wavelength!

I wonder what specific stations you are trying to receive?

I hope that helps.

Happy listening.

(* Aerials such as a Half Wave Dipole or Quarter Wave would, in practice, be about 5% shorter than the actual calculated length)

Geoff replied: *Hi Mike, Thank you for getting back to me so soon, and thank you also for the detailed explanation. It is difficult to find someone with such knowledge nowadays. Yours is a dying art among the general community.*

It seems I have it working as well as can be expected. I have added a secondary single turn loop. It has helped the gain considerably. So much so that I often receive signals from Asia which drown out the Australian ones on some stations. Not the antenna's fault I know.

I now want to add some coax so that I can mount the antenna on a stick above ground outside the building at about 10 metres height. So the receiver will be about 15 metres from the loop antenna. Is that going to work without a booster. If a booster is needed, can you suggest a good one.

Thank you so much. Appreciate your advice. I don't have a lot of neighbours close about who I could ask for such advice.

Yours faithfully, Geoff Douglas

Hi Geoff, You can use coax to connect the loop to a radio receiver. The effectiveness can depend on the receiver itself - some tuners work quite well with a direct connection, while others may be overloaded and would work better with an inductive coupling coil placed near, or on their own ferrite bar antenna.

A booster should not be required, but it may be possible to use something like a differential amplifier, perhaps, if one was needed. I doubt it will though.

With regard to remote location; bear in mind that once placed away from the radio receiver, the loop will be tuned to just one frequency - one station. To change the frequency, you'd have to go outside every time and re-tune the 320pF capacitor! I would experiment first; the performance should be better outside, but the difference may not be worth the bother. Remember too that the aerials components would have to be fully and effectively weather sealed.

Best wishes, Mike.
--

Hi Mike, Thank you indeed for sharing your knowledge. It is nice to communicate with someone who is clued on these subjects.

I should have mentioned earlier, the receiver is a Sangean ATS- 909. It has a external antenna jack, as well as the ferrite rod and telescopic. It also has adjustable gain control. The frequencies I am most wanting are between 540 khz and 700 khz. There is the odd commercial station around 1100 - 1400 khz, but they are not critical.

Thank you for the heads up on the external antenna set up. I was planning to make it demountable so that it can be inside in inclement weather and in situations where it is not needed externally. We have pretty dry conditions mostly anyway, and no frosts at all.

Other folk around here are very interested in your thread. So you are helping several other than just me.

Thank you again, Cheers, Geoff.

Hi Geoff, It's worth trying a direct connection to the ATS-909 if it has a variable gain control. The usefulness of the gain control depends on where it is placed in the front end circuit. If is is placed after the first stage of any RF amplification, it may not be entirely effective with strong signals as the first stage may already be overloaded before reaching the subsequent gain control.

Overloading will be noticeable by an increase in background noise and inter-modulation problems, for example. In which case you could add a variable attenuator into the feed-line, or simply use inductive coupling to the radio's internal ferrite bar antenna.

With regard to some stations being swamped by other stations from Asia, then you can try rotating the frame aerial to null out the interfering signal. The the nulls are fairly sharp and can help reduce the unwanted station enough to make the wanted station audible. The long distance interference will no doubt be received at dusk and after dark when the lower D Layer (about 50 miles above the earth) of the ionosphere dissipates and allows signals through to be reflected from the higher F Layers (about 100 to 300 miles above the earth) in the ionosphere, causing longer distance (DX) reception of those stations.

I am glad that others are interested in this idea too!

Thanks for getting in contact.

Best wishes, Mike.
--

Radio Stations & Memorabilia | **ATU's Aerial Tuning Units** | **Copper Tube Antenna**

DXing & Short Wave | **Make A Signal Meter** | **Riding On A Radio Wave**

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CRYSTAL SETS 2

Some Practical Designs
MAKE YOUR OWN
CRYSTAL SET !!

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Crystal Sets Introduction | Resistor & Capacitor Conversion Tables

Crystal Sets (Part1) | Spider's Web Crystal Set (Part 3

Crystal Set by Kenneth Rankin (Part 4) | Experimental Crystal Sets (Part 5) | Crystal Radio Links

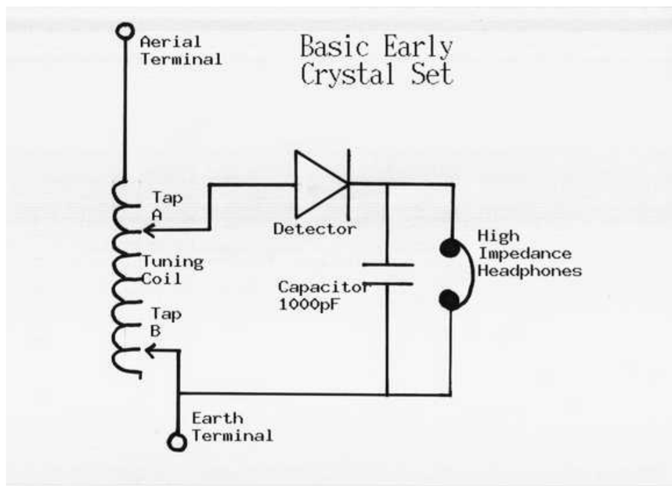
CRYSTAL SETS 2: SOME PRACTICAL DESIGNS

I hope that you attempt building one or two of these crystal set designs and I really do recommend that the components are carefully connected up using soldered joints onto a piece of tag-strip for reliability. However if you are new to constructing such electronic circuits then some simple solder-less techniques could be employed and these are suggested at the bottom of the page. Also see Crystal Sets Part 5 for more ideas on experimenting with crystal sets.

An early and very basic crystal set would have been nothing more than a coil of wire, perhaps 50 -100 turns, wound around a cardboard tube about 3 inches (7cm) in diameter, a detector (or cats whisker) and a pair of special High Impedance headphones (as discussed in part 1).

There would be a very large aerial strung up around the garden and the all important connection to earth.

The coil would have tapping points (connection points) at intervals of around 5 or 10 turns. See the circuit diagram on the right for details of who the set is wired together.



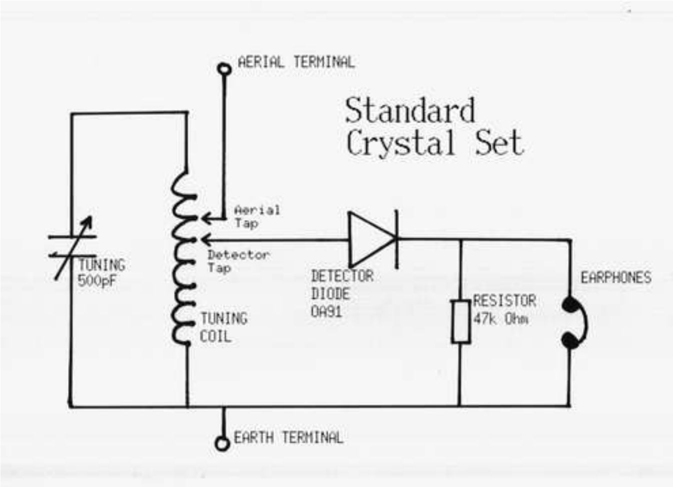
A very basic crystal set circuit.

The tapping points on the coil allow the set to be tuned to different frequencies by adjusting the position of tap B. Tap B would be connected to the coil at differently positions by way of a crocodile clip. The fewer turns between the top (aerial end) of the coil and tap B, the shorter the wavelength received (ie the higher the frequency). Tap A would allow the detector to be connected at different positions to vary performance. There is an additional component drawn in the above diagram, the *capacitor* (value 1000pF), this is included in crystal sets that used the *High Impedance* magnetic headphones, and bypassed any remaining radio frequencies (RF) to earth.

I have not built the set described above as it is so basic. Such a crystal set above would probably have been adequate in 1920 - 1923 when there would have been only one local transmitter receivable.

When the BBC expanded transmissions and it became possible to hear more than a single station it would have became necessary to include a more convenient means of tuning the set.

This was achieved by including a Variable Tuning Capacitor, of about 500pF (0.0005uF) connected in parallel with the tuning



The Standard Crystal Set

coil forming a *tuned circuit*. The tuning capacitor would have a Bakelite knob on the spindle to aid tuning.

Because of the simplicity of crystal sets, it is often difficult to separate stations. When tuned into one station it is often possible to hear another close by station in the background, this is due to lack of *selectivity*. This can be reduced somewhat by adjusting the positions of the Aerial Tap and Detector Tap. Moving them closer to the bottom of the coil, the earthy end, reduces the load on the tuned circuit and this improves selectivity, however it does also reduce *sensitivity* which can make the station quieter. Headphones will often swamp a tuned circuit and reduce its selectivity (Q factor), so moving the tapping point lower down improves this situation. Every circumstance is bound to be different though so the best balance has to be found by experimentation. My crystal set has both the diode and the aerial connected to the same tapping point on the coil, about a quarter of the way down.

The modern 'standard crystal set' shown above uses a Crystal Earphone, since suitable high impedance magnetic headphones (of 2000 to 4000 ohms) are no longer widely available. When using a crystal earpiece the 1000pF capacitor shown in the first diagram can usually be omitted an in its place a 47k ohm resistor is connected, this ensures that the Crystal Earphone will work at its most efficient i.e. the sounds will be as loud as possible. The resistor allows DC current to flow through the circuit efficiently - this would otherwise be blocked when using a crystal earphone. In a modern crystal set the detector used is a *Diode.* Suitable diodes include OA80, OA81, OA90 OA91 and IN94 which are usually available from component stockists.

A Better Diode For Increased Efficiency

The OA47 will be of particular interest since it has the lowest forward bias voltage of any of these diodes which will make the crystal set somewhat more sensitive and therefore louder. The US equivalent of the British OA47 is the IN34.

On the right you will see my real working example of a crystal set

The large plastic knob on the front turns the variable tuning capacitor. This set receives the three UK national stations and also three local radio stations very well at my location.

There is a small 3.5mm jack socket mounted on the front of the plastic case (MB5 from Maplin Electronics) that the crystal earphone plugs into.

The coil can be seen inside the case, it is 70 turns of 30 gauge enamelled copper wire wound around the centre of a toilet roll and tapped every 10 turns, by scraping off the enamel insulation and making a small twist. The croc' clips can be seen clipped on to these twists to connect to the aerial and detector tap points.

A real working crystal set. Radio as if by magic with no battery or mains power.

THE MEDIUM WAVE COIL - MORE DETAILS

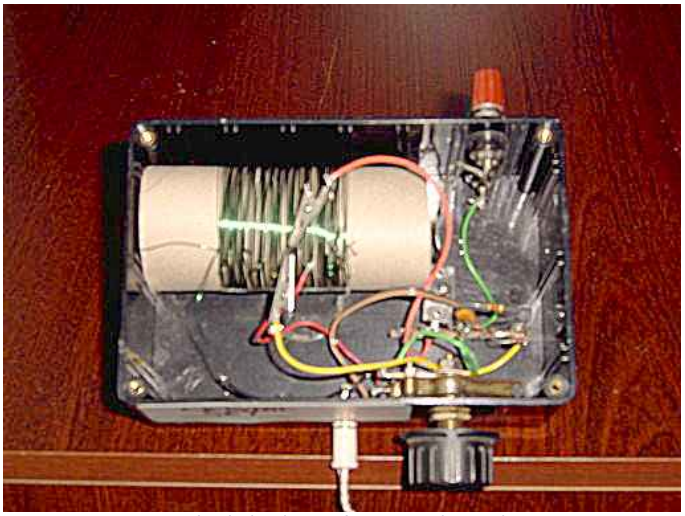


PHOTO SHOWING THE INSIDE OF
THE COMPLETED CRYSTAL SET

Medium Wave Coil

The number of turns of wire required on the coil will vary depending on the size of the former (in this case the inside toilet roll) and the thickness of the wire. So to obtain the correct coverage of the medium wave band may need a little experimentation.

I usually find that between 50 to 90 turns is right and I generally use enamelled copper wire that is between 30 s.w.g. and 26 s.w.g (i.e. 0.315mm and 0.45mm diameter), so it's best to start with too many turns and then work down.

The more turns that you use the lower the frequency range will be, i.e. too many and the coverage of the top end of medium wave around 1500 - 1600 kHz will be lost, while too few and the coverage down to 500 kHz will be lost.

It is also important that the coil former is non conducting, i.e. not metallic. It could be wood or cardboard or a short piece of PVC piping and with a diameter of between 1½ and 4 inches (4 to 15 cm) are common sizes. You could try using a ferrite rod too, see below.

This particular set has a coil wound onto a toilet roll tube which consists of 70 turns of 30 s.w.g. (0.315mm dia) enamelled copper wire tapped at every 10 turns. It also has the additional small trimmer capacitor that helps match the aerial to the tuned circuit thereby improving selectivity, see below.

USING A FERRITE ROD AS THE COIL FORMER

The aerial coil could be wound onto a ferrite rod.

A piece of 10mm diameter ferrite rod of between 3 and 6 inches long (80 to 150mm) will be most suitable and will require between 50 and 90 turns of enamelled copper wire to provide coverage of the medium wave band: First make a paper tube that is held together with sticky tape that will easily slide up and down the ferrite rod. Then wind the coil over this with the windings neatly side by side. Make tapping points every 10 or 15 turns so that the aerial and diode tapping points can be adjusted.

Adjustments to the tuning range can be made by removing some wire from the coil so it is best to start off with too many turns and then work down. Fine adjustments can be made to the completed coil by sliding it up and down the ferrite rod.

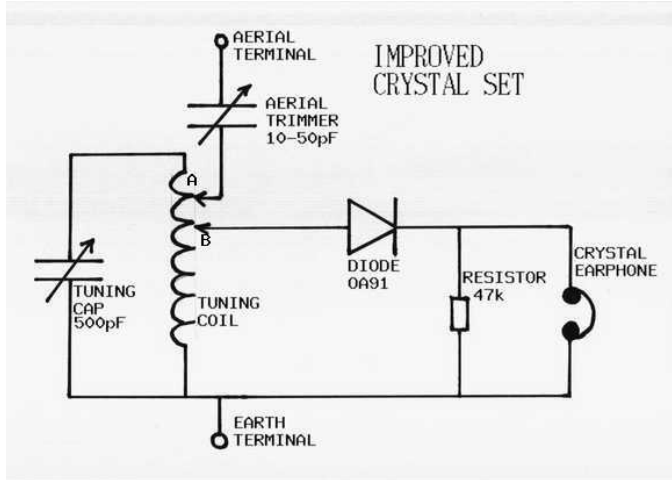
AN IMPROVEMENT TO THE DESIGN

The crystal set above also has one small, but significant, improvement over the standard crystal set and that is an Aerial Trimmer. A trimmer is a variable capacitor, very similar to the tuning capacitor, except smaller and adjusted with a screwdriver.

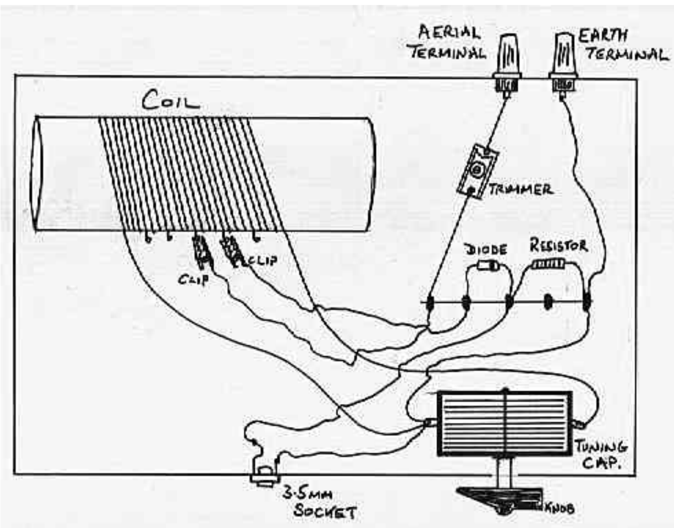
The value of the trimmer is usually around 10 - 50pF, but if a small tuning capacitor is available that will probably be just as effective. In the absence of such a variable capacitor, individual fixed ceramic capacitors of e.g. 10pF, 50pF and 100pF can be tried in this position to judge which gives the best results with the particular aerial being used.

The trimmer capacitor adjusts the coupling to the tuned circuit, reducing the load of the aerial on the tuned circuit will improve

the selectivity (Q), and it will be easier to separate stations. Again tapping points are used and I find this to be an excellent arrangement.



Improved Crystal Set design, with good selectivity



Layout Of The Crystal Set - Although this is soldered together an alternative to tagstrip would be a 5amp mains connector block so that components can be trapped in place with screws. See article below.

The picture on the right shows the general layout of the crystal set above. The coil is of approximately 70 turns is wound on the centre of a toilet roll, and has tapping points at 10 turn intervals.

The trimmer is soldered between the Aerial terminal and the piece of 5-way tag strip, and a wire goes from there to a croc' clip which is clipped onto a tap on the coil. The Diode is also soldered onto the tag strip, one end connected to a piece of wire going to a second croc' clip & connected to a tapping point on the coil, the other end of the diode is connected to the 3.5mm jack socket that the Crystal Earphone plugs into.

The 47k resistor is also connected to the earphone end of the diode and goes to earth, the earth terminal wire is soldered to the tag strip at this point too. The tuning capacitor has two terminals, one connected to each end of the coil, and one of them is also connected to earth as shown. [Where the wires cross over in the diagram, they do not touch and are not connected together].

LONG WAVES

In most areas around Europe and certainly around much of the UK you will be able to hear a Long Wave station. To receive Long Wave on a crystal set will require an aerial coil with a greater number of turns to increase its inductance.

As a good general guide a coil wound on a piece of 10mm diameter ferrite rod will require about 250 turns of enamelled copper wire: First make a paper tube that is held together with sticky tape that will slide up and down the ferrite rod. Then wind the 250 turn coil over this, the windings will have to be made over the top of each other. Make tapping points at, say, 50, 75 and 100 turns to tap the aerial and diode to.

As with the medium wave ferrite rod aerial, adjustments to the tuning range can be made by adding or removing some wire from the coil, and fine adjustments can be made to the completed coil by sliding it up and down the ferrite rod. The longer the ferrite rod the better and anything between 3 and 6 inches long (80 to 150mm) will be very good.

SHORT WAVES

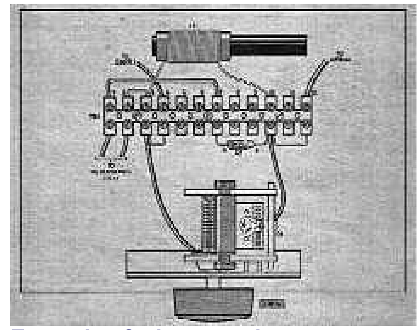
If you like experimenting, then reducing the number of turns on the coil to say 10 to 30 will allow reception of the higher frequencies, the Short Waves. I have found

that winding the coil around a 'ferrite rod' often works even better with short wave reception.

Obtain a ferrite rod about 7 to 15 cm long and about 1cm in diameter. Make a couple of small tubes of card, about 4cm long, that will fit tightly over the rod.

On one tube wind two coils using 0.5mm diameter enamelled copper wire - one coil of about 30 turns and a second one of 2 or 3 turns wound over the top of the first. Secure the windings in place with Sellotape.

On the other card tube wind a similar coil, but use about 15 turns for the first coil and for the second coil wind about 3 to 4 turns over the top, and secure with Sellotape tape.



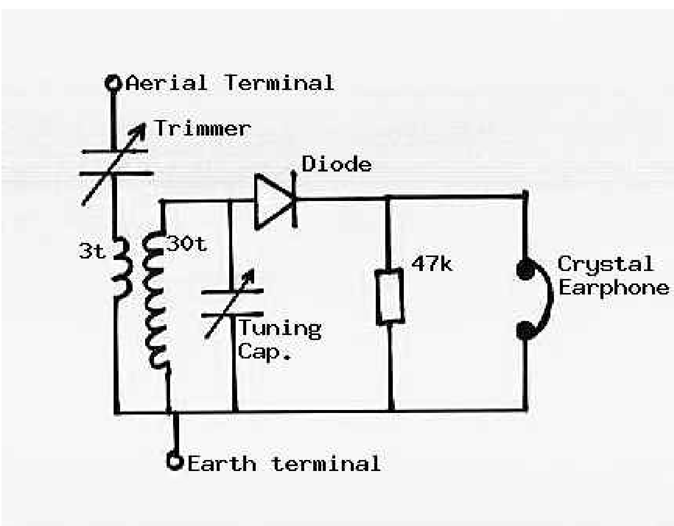
Example of a layout using a connector block to wire up a crystal set

These coils will provide coverage of short wave in two bands using the first coil for the longer wavelengths, typically 60 to 31 metre bands and the second coil for the shorter wavelengths typically 25 to 19 metre band. Wire up the circuit as shown in the circuit diagram below.

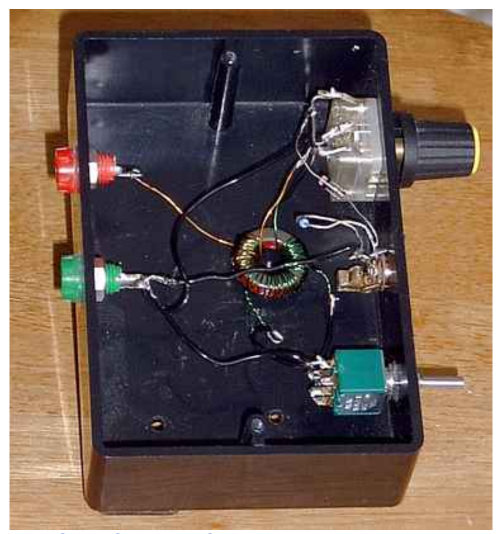
USING A TOROID INDUCTOR FOR SHORT WAVES

Even better selectivity performance can be achieved by winding the inductors (coils) on a ferrite toroids (T50-2 yellow, or green will do). The aerial trimmer need not be used if selectivity and sensitivity is found to be adequate. It's all about experimenting, and I find it best to use a trimmer or small coupling capacitor to obtain the best selectivity.

Up to 30 turns of 0.5mm enamelled copper wire can be used for the longer short waves below 10 MHz, while a winding of around 15 turns will provide coverage of the shorter short waves above 10MHz.



The circuit diagram of the Short Wave Crystal Set



A completed SW Crystal Set using a toroid inductor. Note: the main winding has a tap to allow the switch to short part of the winding and thereby give two ranges.

AUSTRALIAN DESIGN

Moving back to the Medium Waves, here is a circuit for a very interesting Australian design that promises extremely good station separation (selectivity), and having built it I can vouch for that claim, it's really excellent.

I receive three national stations and three local stations at my location with excellent clarity using a modest antenna and standard crystal earphone.

The coil is different to the other crystal sets described above, it is

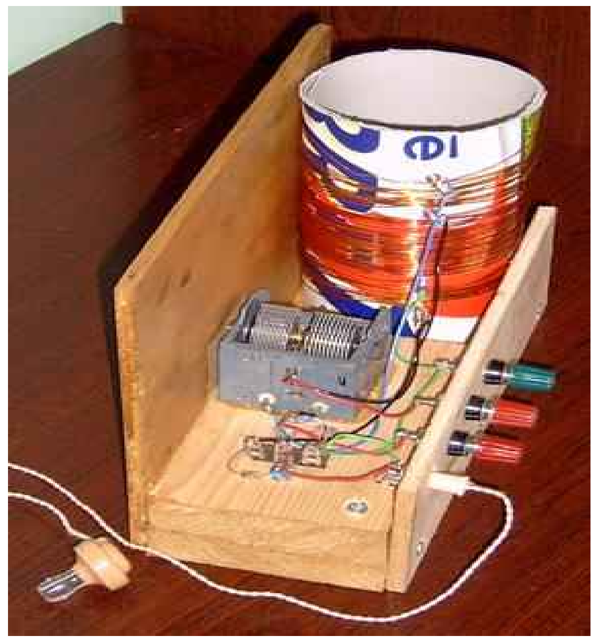
The front panel of the Australian Crystal Set

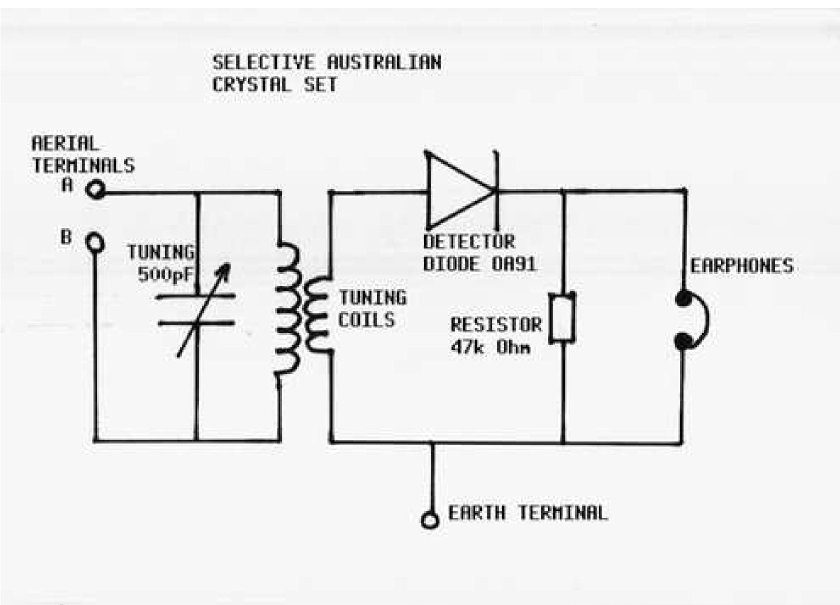
much bigger at 3¼ inches (8cm) diameter and 5inches (12cm) long. I made my coil former out of the cardboard from a breakfast cereal box - just like Blue Peter!

The design is often referred to as The Mystery Crystal Set, by Proton.

Two distinct coils are wound on it, the first one consists of about 50 turns of 24 s.w.g (approx) enamelled copper wire. The second coil is 25 turns, very close wound right over the top of the first coil using 30 s.w.g. (approx) wire, try to get this second coil wound in between the windings of the first, for better inductive coupling.

Then carefully wire up the set according to the diagram. Notice that the tuned circuit is not connected to earth and has no *direct* connection to the detector circuit. The detector circuit *is* connected to earth however. The two aerial terminals offer alternative selectivity performance, terminal A gives very good selectivity while B is very wide. I never bother with B.





Make the coil carefully and wire up this crystal set according to the circuit diagram opposite and you will be rewarded with a really high performance crystal set of a type that was used in the very early days of broadcasting in 1930's in Australia.

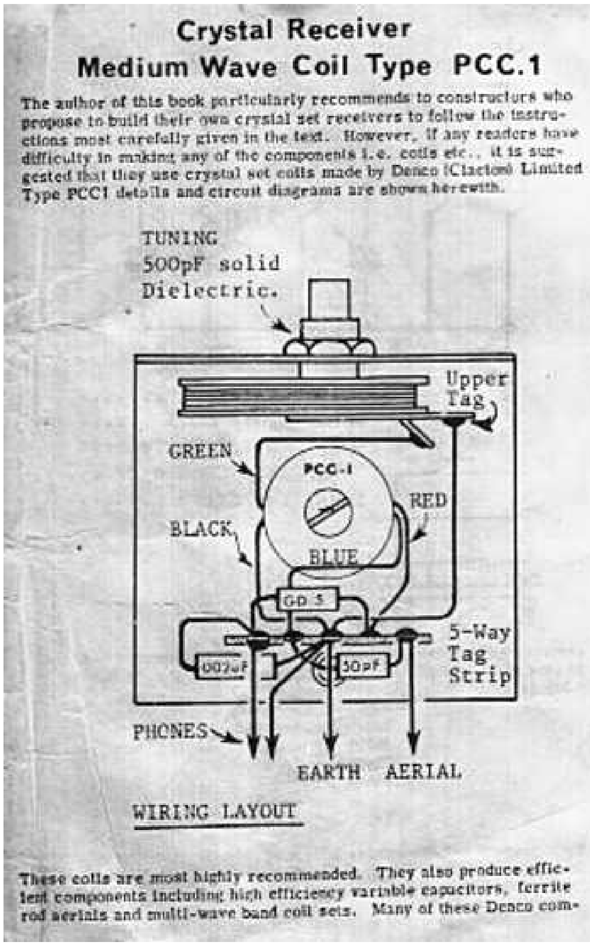
This is probably my favourite crystal set!

THE DENCO PCC1 COIL

The PPC1 coil was a commercially manufactured by Denco Clacton Ltd and was popular among hobbyists not keen on going to the bother of winding their own fiddly little coils. As a child I wanted try one of these coils and sent away for one by mail order. It arrived a few days later in a little cloth bag, like a miniature pump bag, with protective wrapping inside.

The coil windings are entirely enclosed in what I can only describe as a cylindrical ferrite 'shell', the four very thin connecting wires exiting, two either side, from small apertures in the 'shell'. The performance of the circuit shown below I seem to remember was quite pleasing. Unfortunately I cannot find the set or the PPC1 coil at the moment, but here is

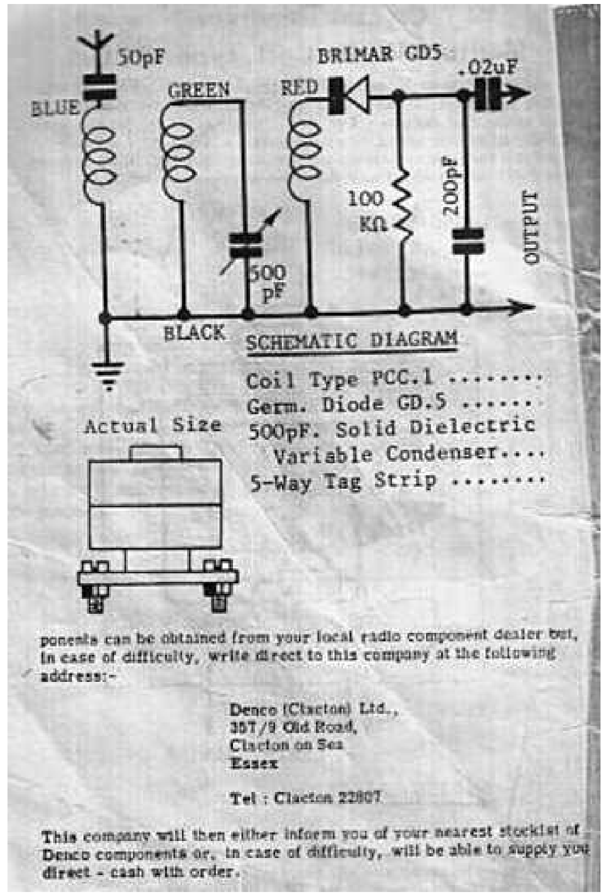
a reproduction of the circuit diagram and data:



Crystal Receiver
Medium Wave Coil Type PCC.1

The author of this book particularly recommends to constructors who propose to build their own crystal set receivers to follow the instructions most carefully given in the text. However, if any readers have difficulty in making any of the components i.e. coils etc., it is suggested that they use crystal set coils made by Denco (Clacton) Limited Type PCC1 details and circuit diagrams are shown herewith.

These coils are most highly recommended. They also produce efficient components including high efficiency variable capacitors, ferrite rod aerials and multi-wave band coil sets. Many of these Denco com-



Coil Type PCC.1 ....
Germ. Diode GD.5 ......
500pF. Solid Dielectric Variable Condenser....
5-Way Tag Strip ....

ponents can be obtained from your local radio component dealer but, in case of difficulty, write direct to this company at the following address:-

Denco (Clacton) Ltd.,
357/9 Old Road,
Clacton on Sea
Essex

Tel : Clacton 22807

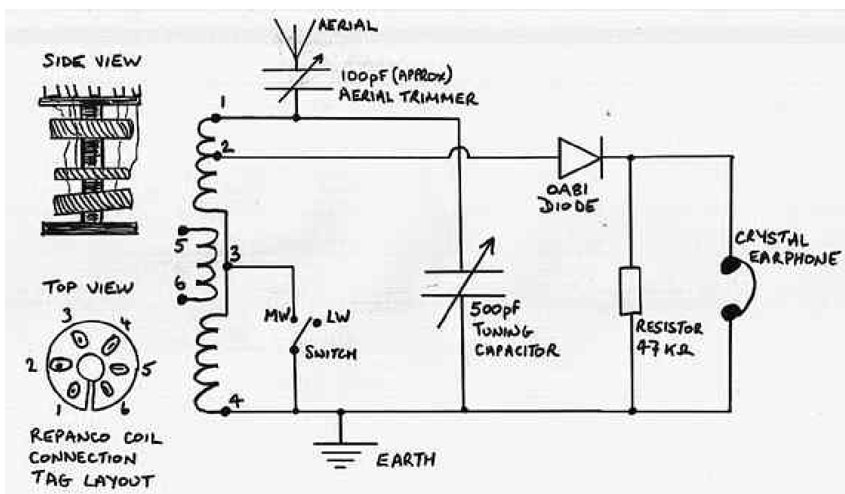
This company will then either inform you of your nearest stockist of Denco components or, in case of difficulty, will be able to supply you direct - cash with order.

THE REPANCO DRR2 COIL

I recently rediscovered an old Repanco DRR2 Longwave / Mediumwave coil that must have been kicking around in my junk box since the 1970's.

The DRR2 coil was made by Repanco in Coventry. It came with a page of suggested circuit diagrams which I thought had been lost to the mists of time, but it recently came to light again, so I have now copied it below.

Once again I included an aerial trimmer which can be adjusted to improve selectivity.



The circuit diagram of the crystal set using the Repanco DRR2 coil

Repanco Ltd was formed by two ex-army signals engineers and from the earliest days of radio supplied crystal set kits and coils to radio construction enthusiasts.

The Repanco DRR2 coil was for medium wave and long wave intended for use in when building simple crystal set and valve radio

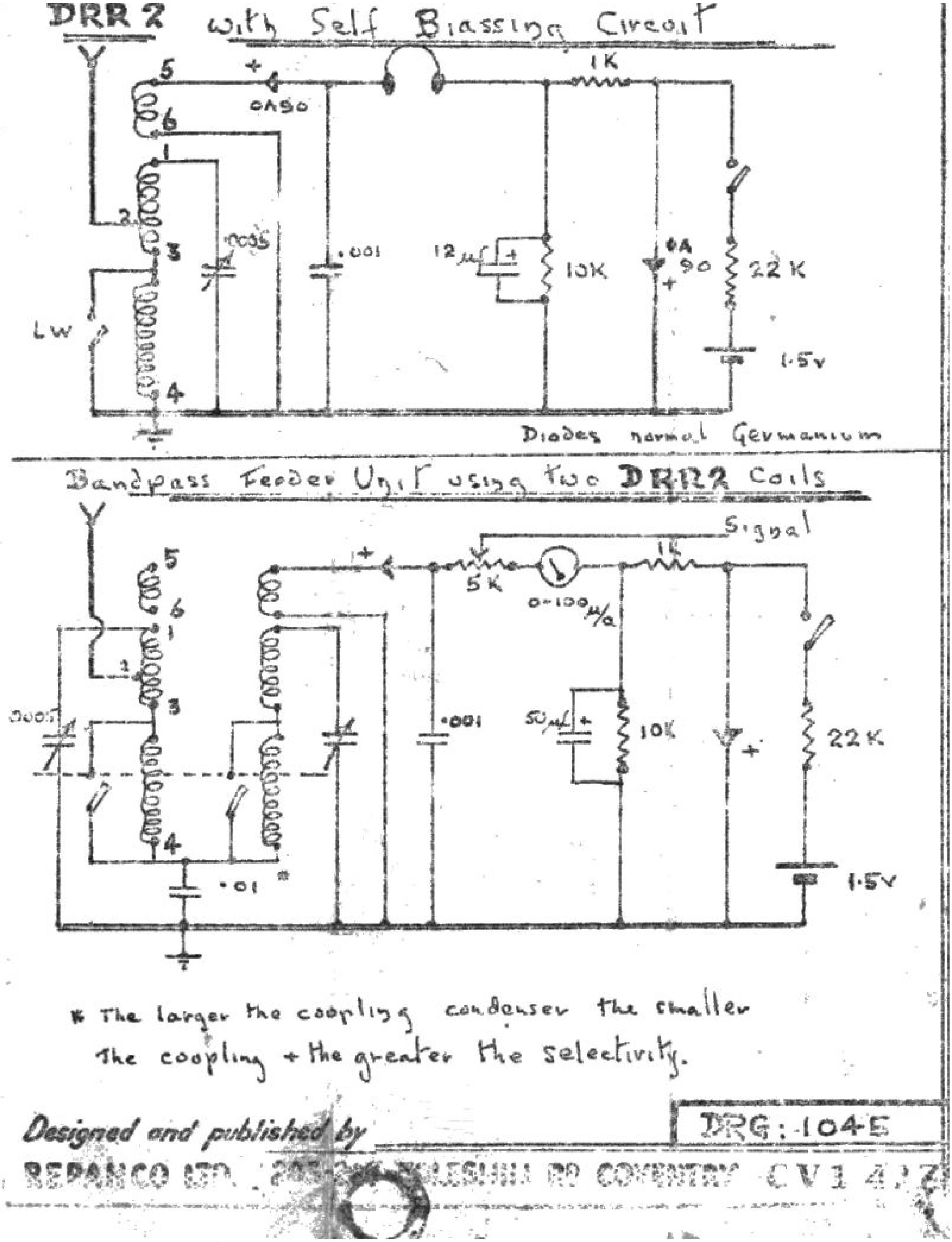
A 'lash-up' of the Repanco crystal set

circuits.

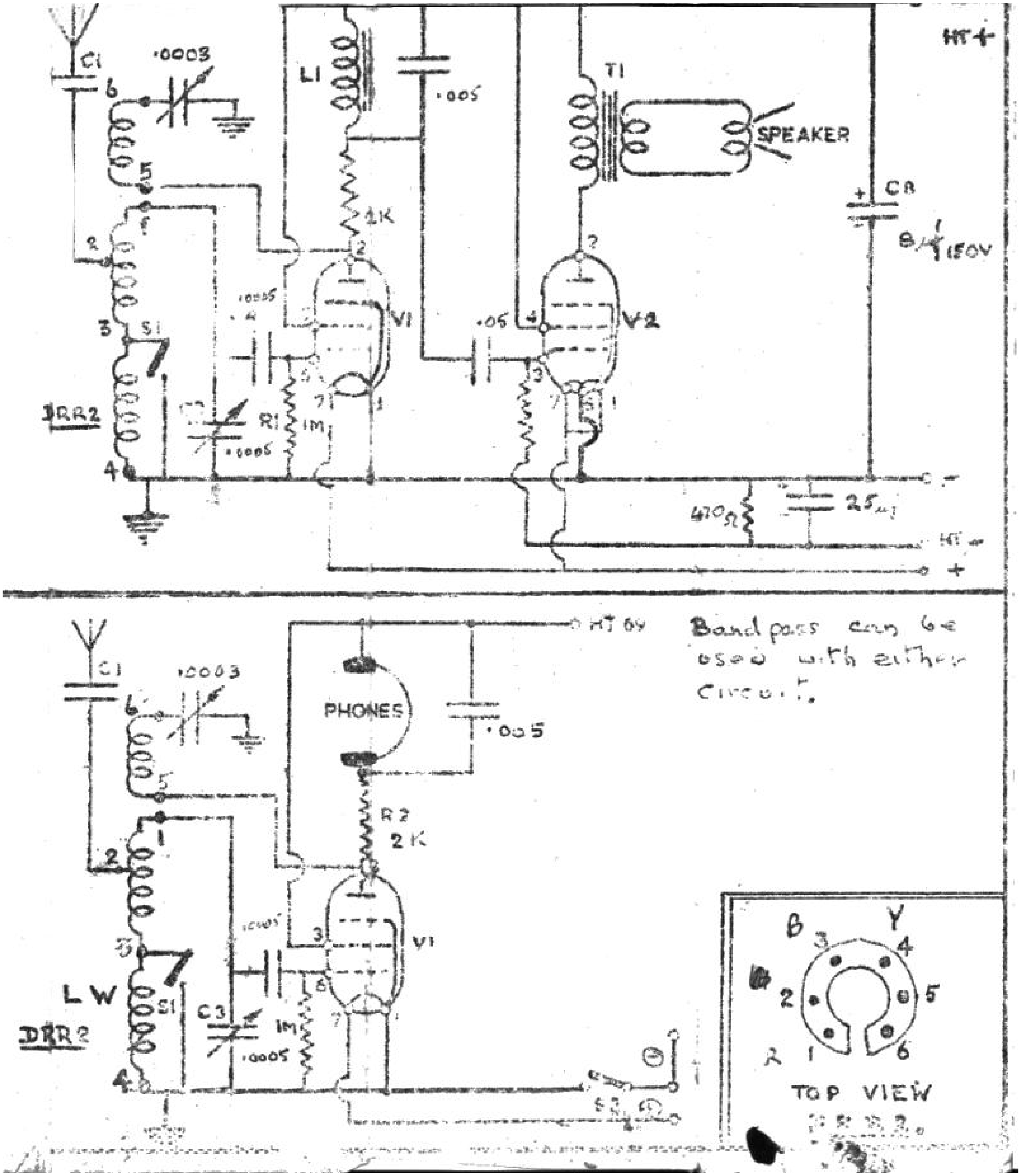
It consists of three coils; a Medium Wave coil at the top that includes a tapping point (for the aerial); a coupling coil or tickler in the middle; a lower coil which can be connected in series with to top coil to provide Long Wave reception.

I have built a quick crystal set with the coil and it provides good reception with excellent selectivity, so it must have a very good Q factor.

The Repanco DDR2 coil was provided with a simple Foolscap size information sheet that showed four different radio circuits. Sadly the sheet does not give a huge amount of information and my copy is now rather tatty and faded - it is copied below:



Simple crystal radio type circuits using the Repanco DRR2 coil

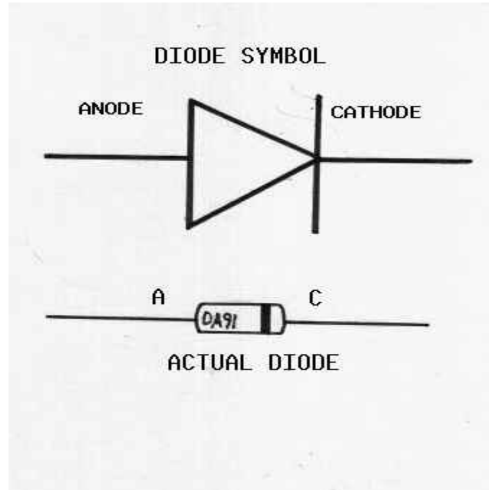


Valve circuits using the Repanco DRR2 coil

Repanco Ltd no longer produces radio coils and crystal set kits for the radio construction enthusiast, as it did in the early days of radio. In 1986 it was renamed Repanco Bartlett Ltd when it merged with Bartlett Electronics. The company moved from the Foleshill Road to Unit 24, Albion Industrial Estate, Endemere Road, Coventry CV6 5NT and now specialises in transformers and wound components and can design and manufacture to commercial customer requirements, their website is: http://www.repancobartlett.co.uk/

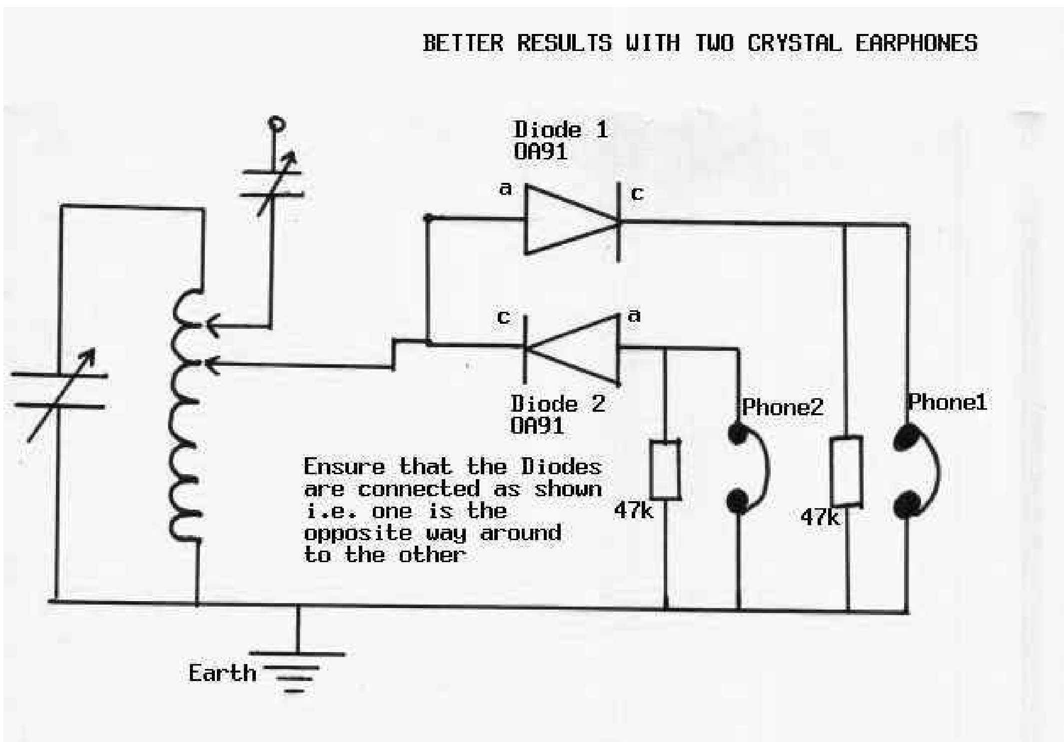
CRYSTAL EARPHONES

Here is a good idea and well worth trying, to maximise the use of sound output from your crystal set why not use dual crystal earphones? Having an earphone in each ear helps to block out extraneous noises helping the listener to better concentrate on any weaker stations received.



Using the circuit below, one earphone makes use of one half cycle of the radio wave while the second earphone uses the other half cycle of the wave that would have previously gone to waste when using just one diode. Ensure that the diodes are connected up according to the diagram i.e. one diode is connected the opposite way round to the other.

Also try to make sure that the diodes and crystal earphones are similar to obtain the best results. (You could simply connect two crystal earphones to the same terminals of the single diode, but this would not be as efficient and the sounds would be much quieter.)



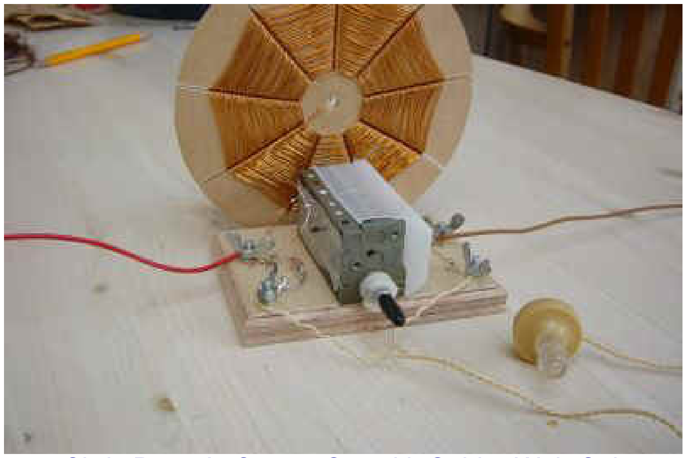
A note about Crystal Earphones: It will be worthwhile buying several different ones from different sources as performance varies between manufacturers quite markedly. I have found the ones marked 'Japan' on the back are the most sensitive and therefore loudest, whereas ones marked 'Receiver' 'Taiwan' are often a little less sensitive and therefore quieter and sometimes more 'tinny' sounding.

As mentioned previously it has been noted that the OA47 diode will be of particular interest since it has the lowest forward bias voltage of any of the common diodes available. This will make the crystal set somewhat more sensitive and therefore louder. The US equivalent of the British OA47 is the IN34.

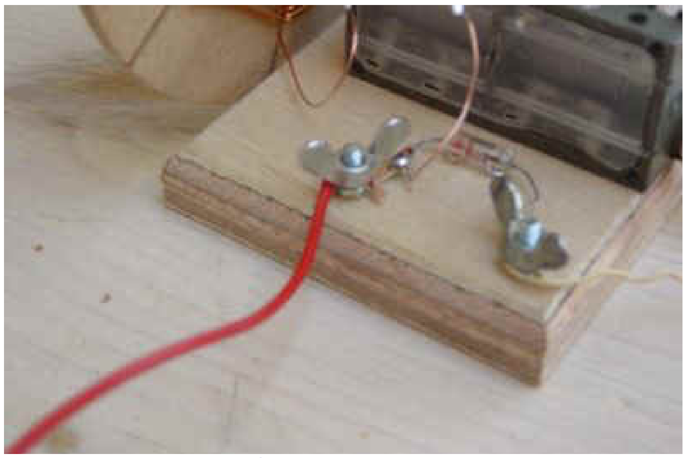
SPIDERS WEB' COIL

Here is an interesting concept sent in by Chris Dorna of the Vught North Scouts in the Netherlands. It is a crystal set made out of a coil wound in the form of a spiders web:

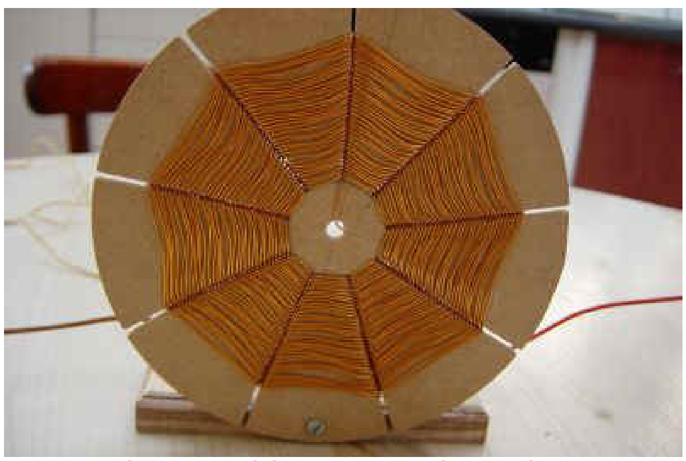
See more HERE.



Chris Dorna's Crystal Set with Spider Web Coil



Detail of the germanium diode



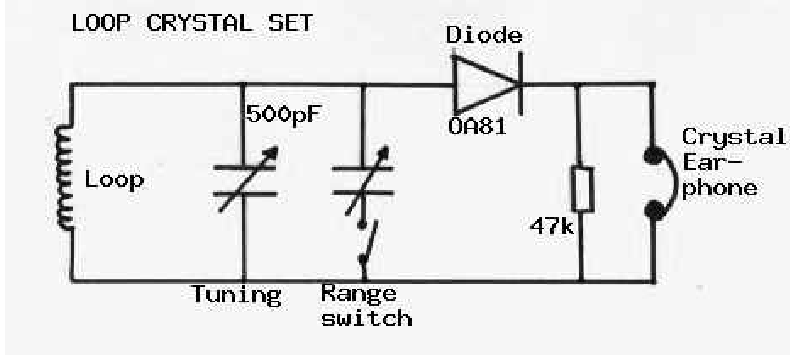
Close up of Chris Dorna's Spider Coil

LOOP THE LOOP!

A crystal set can also be made that does not need a large long wire aerial. If you have ever made a loop aerial for medium wave or long wave DX-ing, then it is a simple matter to add a diode, resistor and a socket to connect a crystal earphone that will allow reception of nearby stations.

See my section on [Loop Aerials]() and ATU's for more constructional details.

A portable loop aerial, that incorporates a crystal set



The circuit diagram of the Loop Crystal Set. The loop is 10 turns of 7/0.2mm 'hook-up' wire wound on a 40cm (17") former made of attractive plastic edging strip available from many DIY stores. The loop is very directional in its pick up pattern, which can help eliminate interference from some stations by rotating the loop. The switch and additional capacitor allow tuning of the lower medium wave band from about 650 to 520 kHz. Having a loop with 50 to 60 turns of wire will tune into the Long Wave band.

DIODES - For Crystal Set Use - some notes by Felix Scerri

Germanium diodes for crystal set use.

Although I'm a fan of these new silicon schottky BAT 46 diodes, good germanium diodes still have a lot to offer, especially in terms of 'weak signal' sensitivity. Last night I did an experiment.

I sorted through quite a few of my hundreds of acquired random germanium diodes looking for particularly 'sensitive' ones. I tested this by tuning in a weak AM station and comparing the detected DC output level and also the apparent 'loudness' of the audio signal.

Even amongst germanium diodes of the same type, there was enormous variation all the way from excellent to poor! For very weak signals, germanium diodes 'detect' in the 'square law' region below the diode conduction 'knee', in a rather different part of the curve than with much stronger signals (way beyond the diode knee).

When testing germanium diodes for weak signal sensitivity, the inherent capacitance of the diodes is also a factor, and the 'tuning' may change somewhat and will need to be readjusted with every diode tested!

In the end, out of a large number of germanium diodes tested, I found three or four germanium diodes with excellent weak signal sensitivity and the rest were poor. One other interesting thing, good germanium diodes 'sound' different, rather more 'rounded and smoother' than the schottky's which tend to sound mercilessly clean, almost clinical. I also found almost no variation in weak signal sensitivity with my BAT 46 schottky diodes. Take your pick!

Regards, Felix Scerri VK4FUQ 14/03/2012

SOLDERLESS CONSTRUCTION IDEAS

For a novice the use of a soldering iron may seem a bit daunting at first and while the most reliable results will be obtained with a good soldered joint using a tag strip as shown below, the circuits can still be made without the use of a soldering iron.

5 WAY TAG STRIP

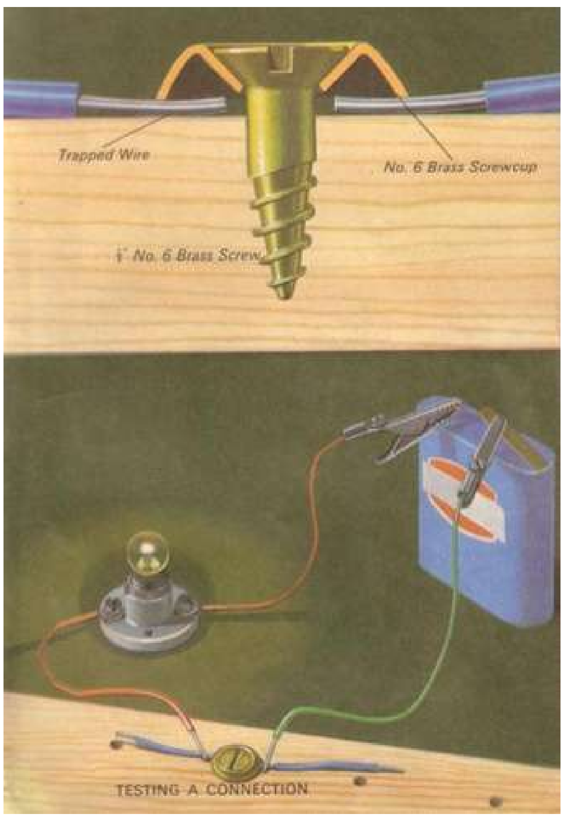
36 WAY TAG STRIP - TWO ROWS

The very simplest circuits could be wired together ,with a little ingenuity, with the component wires being held together in the grip of solderless crocodile clips, whereby the connecting hook-up wire is fixed to the croc' clip by a screw rather than solder.

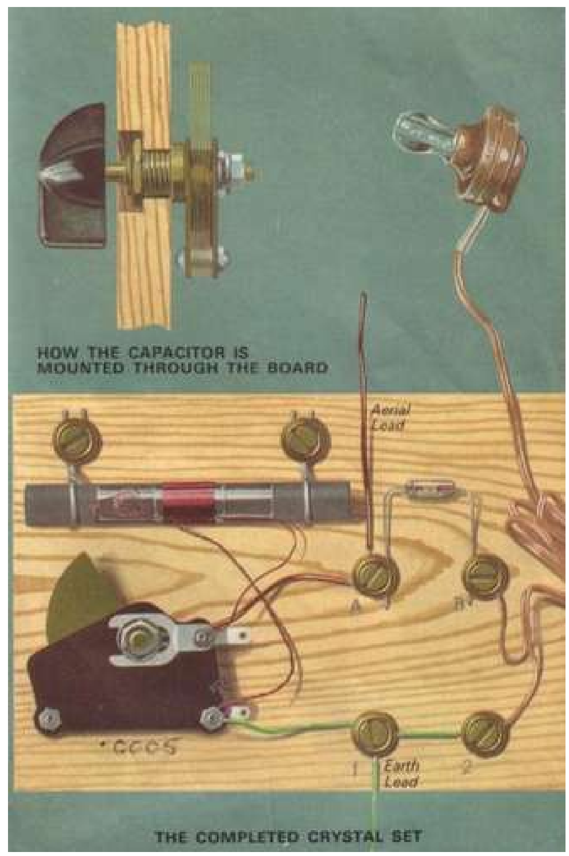
For more the slightly more complex circuits a plastic Terminal Block (sometimes referred to as a choc' or chocolate block) can be utilised very effectively indeed. These are used in mains wiring and are available in various sizes; 2 Amp, 5 Amp, 15 Amp and 30 Amp. The 5 and 15 Amp Terminal Blocks I have found to be the most suitable. The various component wires can be trapped securely with the screw at each junction point. This method also makes it easy to change the components around when experiment with different circuits. See The EXPERMENTAL CRYSTAL SET for more details in Part 5.

'CHOCOLATE' TERMINAL BLOCK

The Ladybird book called 'Making A Transistor Radio' (also shown on the TRF Radio pages) detailed a very novel approach using brass screws with screw-cups to trap the component wires at each junction point:



THE BRASS SCREW AND SCREW-CUP METHOD OF CONSTRUCTION



A VERY SIMPLE CRYSTAL SET USING THE BRASS SCREW AND CUP METHOD

Crystal Sets Part Part 3 >

No AM radio stations or transmitters in your locality or country?

Has your local medium wave broadcast station closed or been moved to VHF/FM or Digital? Don't worry. You can still build and experiment with crystal sets and TRF radios by also buying or even building a simple low power AM transmitter. So, not only can you use your crystal sets but you can also run your own radio station that can be heard in and around your home - playing the music or programmes that you want to hear!

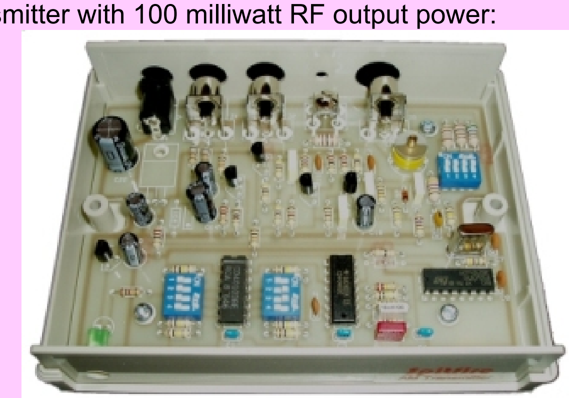
SSTRAN AMT3000: Superb high fidelity medium wave AM transmitter kits from SSTRAN. Versions available for 10kHz spacing in the Americas (AMT3000 or AMT3000-SM) and 9kHz spacing in Europe and other areas (AMT3000-9 and AMT3000-9SM). Superb audio quality and a great and well designed little kit to build: http://www.sstran.com/pages/products.html

http://www.sstran.com/

Other AM transmitters available:

Spitfire & Metzo: Complete, high quality ready built medium wave AM Transmitters from Vintage Components: http://www.vcomp.co.uk/index.htm Vintage Components offer a choice of the high quality Spitfire and Metzo transmitters:

SPITFIRE AM Medium Wave Transmitter with 100 milliwatt RF output power:



http://www.vcomp.co.uk/spitfire/spitfire.htm

METZO AM Medium Wave Transmitter with built in compressor:

http://www.vcomp.co.uk/metzo/metzo.htm

AM88 LP: A basic AM transmitter kit from North County Radio.
http://www.northcountryradio.com/Kitpages/am88.htm

LINKS:

BOWOOD ELECTRONICS - A friendly, helpful and very speedy source for many of your electronic components at prices that won't frighten your wallet!

THE FOXHOLE and P.O.W RADIOS - Simple crystal set receivers used by soldiers during the war and by prisoners of war (P.O.W.'s).

VINTAGE COMPONENTS - A great resource for crystal sets, components, valve radio kits and medium wave AM transmitters!

6V6 - Electronic Nostalgia and Vintage Components

Crystal Sets Part 3 >

Crystal Sets (Part1) | **Spider's Web Crystal Set (Part 3**

Crystal Set by Kenneth Rankin (Part 4) | **Experimental Crystal Sets (Part 5)** | **Crystal Radio Links**

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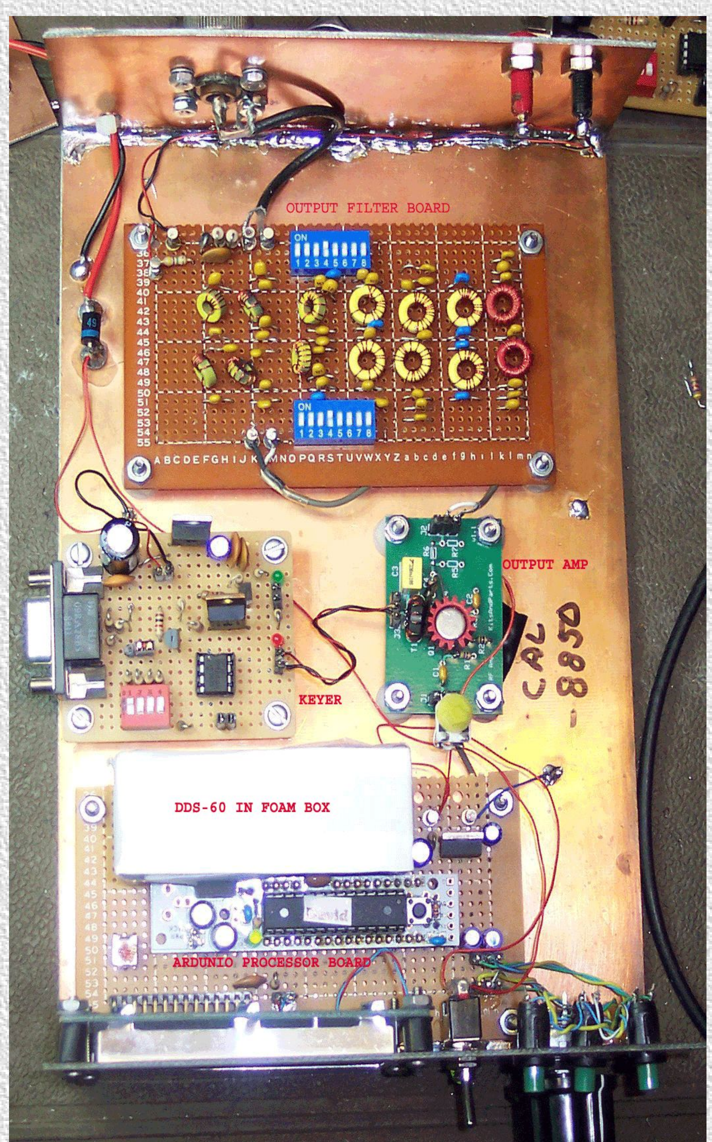
MODEL 5 MEPT

Well, I just couldn't stop. I gave up on model 4 in the middle of development and am now busy building MODEL 5. It is the brain child of Ross KB1KGA. His website is:
http://www.theladderline.com/dds-60
and is chock full of the information to build a copy of his unit. He gives you the complete software program to be loaded into an Ardunio processor which is what he used to control the DDS-60. I put Mine on the air on May 21st and was spotted in Florida, Mass, Utah, Olkahoma, and a smidgin in Alaska. It was only running 160mW on 18,108,900 Hz which is the first time I have been able to operate on that band using QRSS FSKCW. (This thing allows you to work on any frequency from 1.8 Mhz to 60.0 Mhz. I have not tried it on the 136Khz bands but I was tempted. The picture at the left is my interpetation of Ross's schematic and the addition of my transistor transmitter and Multiband Output Filter board and Auxillary keyer modules.



This picture has the new single transistor Output Amplifier from Diz's collection of RF Tookit modules:
http://www.kitsandparts.com/rftoolkits.php

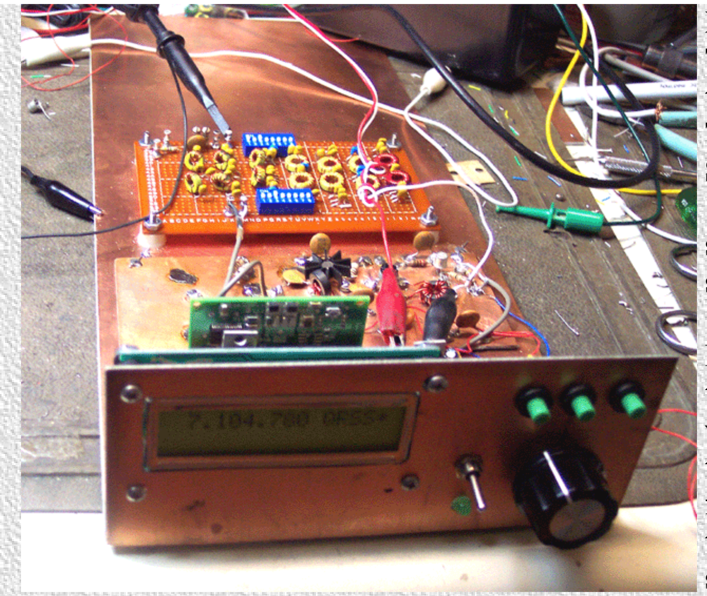
This RF amplifier works very well in continous service giving me about 170mW of power output with 13.8VDC applied. The added heatsink is required for continous service.

The PICAXE 08M keyer was built for the 80 second dits testing in October of 2010.
I was able to be seen on W4HBK's grabber in Pensacola, FL, a distance of 1,163.7 miles away running an output powers of less that 1mW.

This is another view showing the front panel with the readout displaying the frequency. The big knob on the right is the shaft encoder to change the frequency and the three green push button switches are the function switches that change the modes, provide an enter function, and control the frequency steps for the encoder.

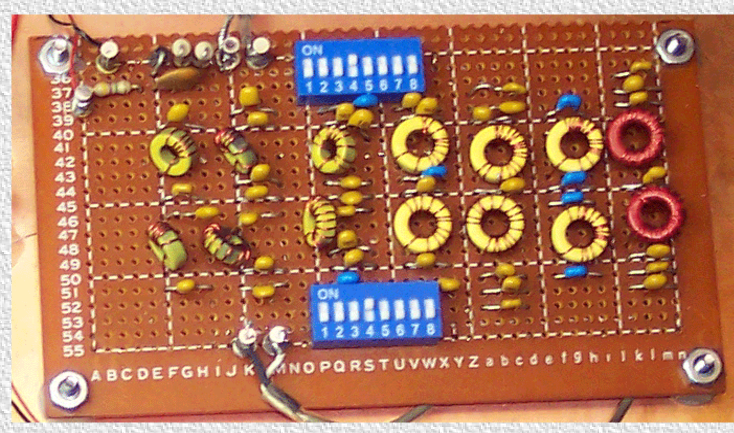
The toggle switch is the on/off power switch and the

little green LED is the power indicator light.
The readout display is also Lit when the unit is on so the little green LED is a bit of overkill.
The readout I used was a Lumx Model LCM S01602DSR/B which I got at DigiKey Part# 67-1769ND for $11.38 each. I found no errors on Ross's schematic and I used the 3rd update schematic and software.

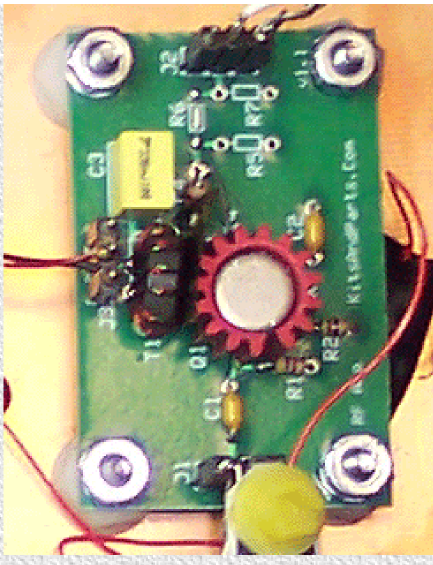


I built the controller on the holed Hobby Board with the single solder circles around each hole and wired it with some left over wire wrap wire that I soldered to the terminals. I used an RBBB Ardunio Kit board from Modern Device and when I built the kit I made the pins point down. Then inserted them into SIP sockets and put them into the hobby board and soldered them. I used right angle pins on the LCD Readout and did the same thing. The DDS-60 which is also available as a kit from the American QRP Club was mounted the same way. Then I turned the board over and did the wiring. On one end I also made SIP plugs for the encoder and function push buttons. It came out as a nice, neat, and functional module.

The Filter board was built on the same type of Hobby board and the dip switches on either side select the different filters. I will try to supply a diagram of this in the near future. It also has a 50 ohm dummy load and a power monitor probe built in so it is easy to adjust the power output. A filter for 80/40/30/20/17/15/10&12 Meters are installed on the board. They were designed using SVC Filter Designer 2.11 from Tonne Software and was a bonus on the CDRom that came with my 2010 ARRL Handbook. The software worked very smoothly and every filter tested out to the same curves that I had printed out when I was using the software. I used some Monolithic Capacitors from JAMECO Electronics. (Only place I could find them in the values I needed)

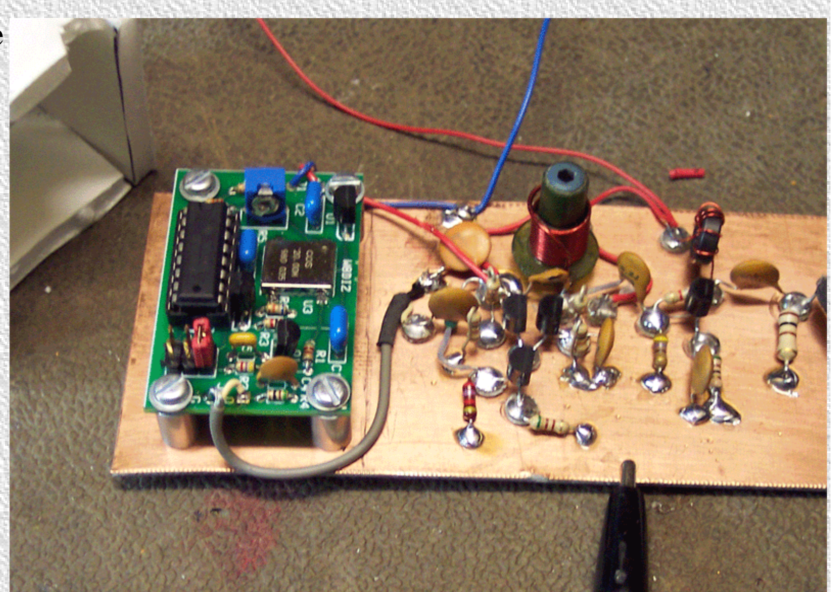


I have already modified this unit by changing the transmitter board to a single transistor RF amplifier Kit sold by :
http://www.kitsandparts.com/rfamp1.1.php
It is a one transistor wide band amplifier to which I added a heat sink to the transistor. I also use a pot to control the drive power to the little amplifier. I can get about 170mW at 13.8VDC which is more than enough to work the world on this mode. Not bad for $8 plus postage. It seems to handle continous key down service very well. I have not had one failure of



this
amplifier since I put it into service over 6 months ago.

Well, I wasn't satisfied with the frequency stability of the DDS-60 Synthesizer. Both of the ones that I built were drifting up and down in the band and the frequency accuracy of the readout could, at times, be quite far off. So, something had to be done. On my MEPT, I installed a GPS 10MHz Disciplined Oscillator, built a 10Mhz to 30Mhz tripler with a amplifier and fed that to my DDS-60 card in place of the 30 MHz crystal oscillator that came with the board. After recalibration, Mine is spot on frequency, No matter where I put it. But my buddy Perry didn't have a GPS Disciplined Oscillator. Thus the birth of the "Secondary Standard". W8DIZ sells a neat Frequency Standard kit for $12 at:
http://www.kitsandparts.com/fref.php
It works like a charm. I added my 10 to 30 MHz tripler and used it's output to drive the 30Mhz oscillator input to the DDS-60 synthesizer. It does very well at start up from a cold start and usually achieves stability in the first 15 minutes of operation. We are now testing for the long term effects of the temperature of Perry's Hamshack. It may need additional heaters, but for now it is working well. I have made up a file of the Frequency Standard schematic, Pictures from W4HBK's grabber of the Startup frequency drift, and a picture of the installation in Perry's MEPT. The .ZIP file can be copied from HERE:
It might be best to SAVE TARGET AS to download it to your computer. I did this so the schematics would be clear and easy to use.



back to MEPT Transmitter page

Pacific Antenna Buddy Keyer and Speaker Console

The Buddy Keyer Console kit provides the builder with an audio amplifier, with speaker, and keyer using KD1JV's SKC (simple keyer chip) in a custom compact brushed aluminum chassis.
It is ideal for any earphone only and or key only device.

Steve's microcontroller chip employs two 29 character memories, adjustable speed from 5-40 wpm, sleep mode for low power consumption, and beacon mode.

It is powered by an internal 9v battery. With the removal of an internal jumper, you may also use this as a standalone code practice oscillator with your paddle.

The kit comes complete with all the electrical/mechanical components, chassis, and decals. It uses all through hole components, and can be easily assembled with the normally available kit building tools.

Current during receive ~10mA, keying ~20mA.

Total assembly time 1~2 hours. Battery not supplied.

Pacific Antenna
www.qrpkits.com
qrpkits.com@gmail.com

We'll start the kit process by identifying and matching the parts with the list below.

Electrical parts

Qty.	Part	Description
1	R1	22K 1/4 watt resistor (red-red-orn)
1	R2	10 ohm 1/4watt resistor (brn-blk-blk)
1	R3	10K potentiometer w/S2 switch
2	R4,R5	2.2K 1/4 watt resistor (red-red-red)
2	C1, C6	.1uF capacitor yellow, marked (104)
3	C2, C3, C4	.01uF capacitor yellow, marked (103)
1	C5	.047uF capacitor, yellow, marked (473K)
1	C7	.001uF capacitor yellow, marked (102)
3	C8, C9, C11	10uF electrolytic capacitor
1	C10	100uF electrolytic capacitor
1	U1	ATTINY13, 8 pin dip microcontroller IC
1	U2	LM386, 8 pin dip amplifier IC
1	U3	78L05 voltage regulator
2	Q1, Q2	2N7000 MOSFET transistor
1	D1	1N4004 diode
1	D2	LED, red
3	J1, J3, J4	Stereo PCB jack
1	S1	Rt. angle pcb push button switch
1		8 pin dip ic socket
1		2" speaker
1		9V battery clip
1		2 pin header and jumper
5'		24awg hook-up wire
1		Printed circuit board

Mechanical parts

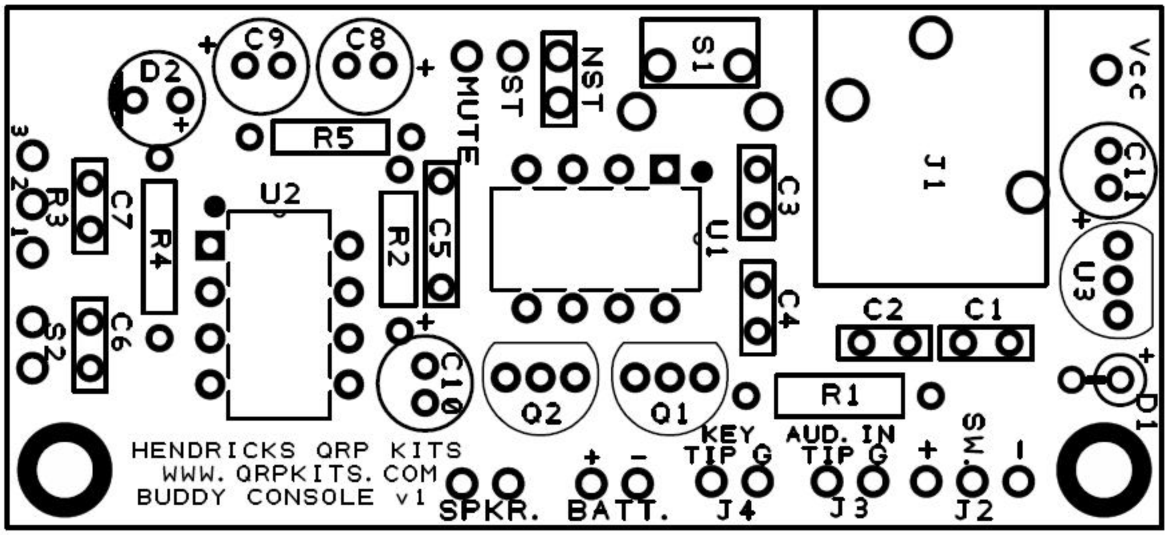
1	Chassis, base and cover
2	Speaker retainer clips
2	4-40 x 1/4 pan head screw
2	4-40 x 1/4 flat head screw
2	4-40 x 3/8 flat head screw
2	2mm x 8mm pan head screw
2	2mm hex nut
1	Instrument knob
4	Self adhesive rubber feet
1	Decal set

Note: Installing the decals to the chassis is addressed at the end of this document, in Appendix A.

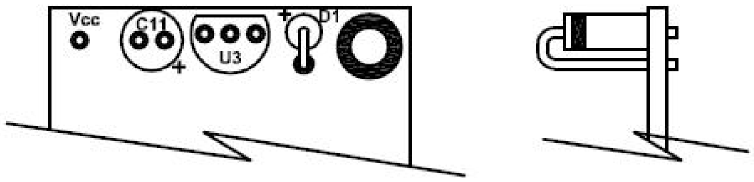
Any first time kit builder should not proceed until you are confident that you can identify each part.

All the pcb components mount on the silk screened side of the board. We will start by installing the smallest and shortest components first.

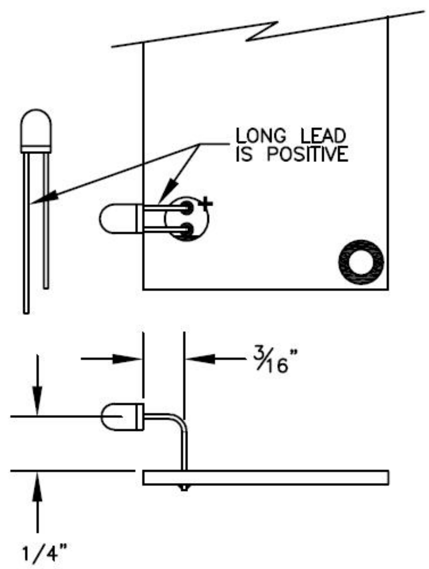
Refer to the graphic below to guide you through the process. Check the items off as they are completed. Clip all leads on the back side 1/16” or shorter.



- ○ Install and solder R1, 22K (red-red-orn)
- ○ Install and solder R2, 10 ohm (brn-blk-blk)
- ○ Install and solder R4, R5, 2.2K (red-red-red)
- ○ Install and solder C1, C6, .1uF, yellow, marked (104)
- ○ Install and solder C2, C3, C4, .01uF, yellow, marked (103)
- ○ Install and solder C5, .047uF , green, marked (473K)
- ○ Install and solder C7, .001uF, yellow, marked (102)
- ○ Install and solder the 8 pin IC socket at U1, the notched end of the socket should match the silk screened outline. The pin 1 corner of the pads is also designated by a square pad at the upper left corner.
- ○ Install and solder U2, the NJM386BD. The printed dot or recessed dot designates pin 1. It must align with the square pad at the U2 position. **Be sure you know which is pin 1, as ic’s are difficult to remove without damaging the board.**
- ○ Install and solder U3, 78L05 voltage regulator, matching the flat with the silk screen outline.
- ○ Install and solder Q1 and Q2, 2N7000 transistors, matching the flats with the silk screen outlines.
- ○ Install and solder S1, the right angle push button switch. Solder the two mounting tabs as well. Be sure to clip the mounting tabs and switch leads on the backside.
- ○ Install and solder D1, 1N4004, vertically, with the **BAND END UP**, matching the board outline. The component is near the edge, with the looped lead towards the center of the board.

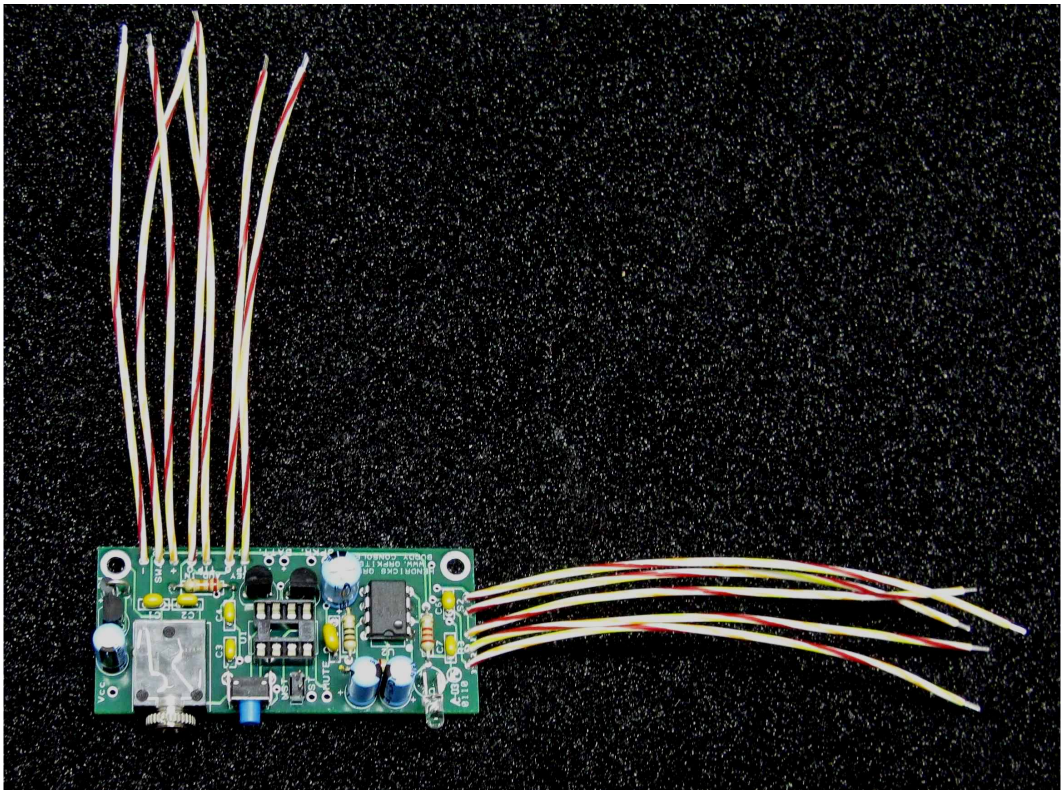


- Install and solder J1, one of the stereo jacks, to the pcb.
- Install the 2 pin header at the NST pads.
- Install and solder C8, C9, C11, the 10uF electrolytic capacitors. The long lead is **POSITIVE** and must match the “+” hole marked on the pcb.
- Install and solder C10, 100uF electrolytic capacitor. The long lead is **POSITIVE** and must match the “+” hole marked on the pcb.
- Installing D2, the red power on led, so that it protrudes through the front panel of the chassis requires that you carefully bend the leads 90 degrees, and solder to the pcb as shown in the graphic below. The long lead is **POSITIVE** and must go into the “+” pad.



- Cut 12 pieces of 24awg hook-up wire, 3” long, and solder them to the following pads of the pcb. J3, J4, S2, and R3.

The board should now look like the picture below.



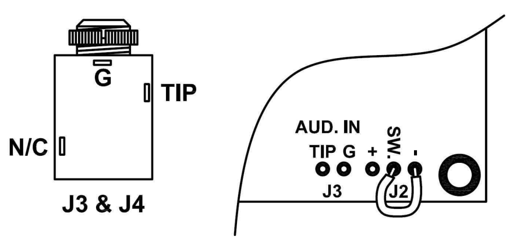
- Shorten tin the red and black wires connected to the speaker to about 4" long.

- Solder the supplied 9v battery snap connector to the BATT. terminals. **Red to "+"** and **black to "-".**

At this point you are ready to attach the remote components to the board. I prefer to leave the leads long, and just tack them during testing, then trim and re-solder to the remote components as required when mounting into the chassis.

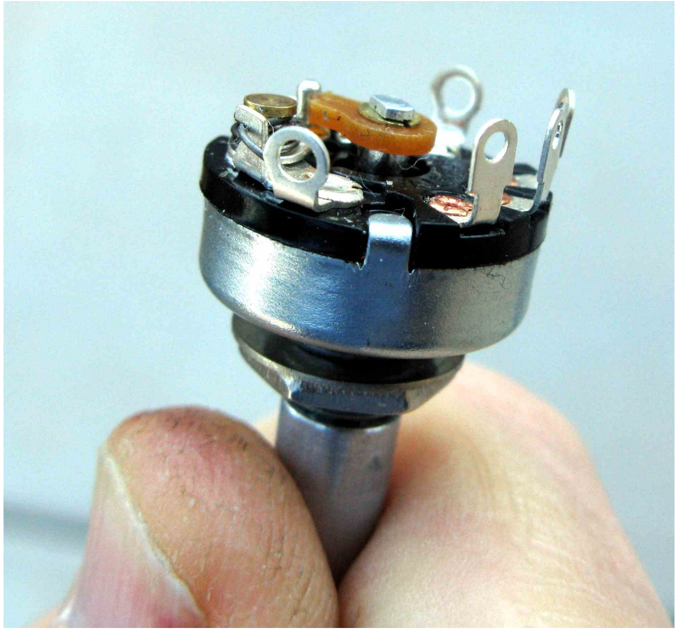
  - Solder J3, J4, the stereo jacks. Only the tip and ground are used for both jacks.

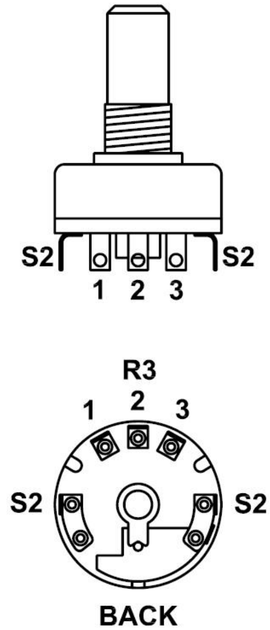
  - Solder a jumper from J2 (-) to J2 (SW). This is necessary due to the unavailability of the switched 12vdc power jack that was used in earlier models.



  - Solder the speaker to the two leads marked SPKR.

- The potentiometer, R3/S2, must be prepared to fit into the case. Bend all 5 tabs to the rear, 90 degrees. Then solder the numbered leads to the pcb as shown, so the gain will increase as you turn the knob clockwise, and solder the switch connections for S2.





Testing

Snap on a 9 volt battery or plug in a 12.0 -13.8 VDC power supply to the 2.1mm jack, J2. The center pin is positive.

With the power switch “ON”, you should see the power led illuminate, and should be able to see +5VDC at Vcc, pin 8 of U1 socket, and pin 6 of U2.

Turn “OFF” the power, and you may now carefully insert U1 into the socket, observing that the small indentation denotes pin 1, and matching it to the silk screened dot on the pcb.

Turn the power back “ON”, advance the volume control, and you should be able to press the push button “FUNCTION” switch and hear the tones indicating the operation of the keyer described in the operating section.

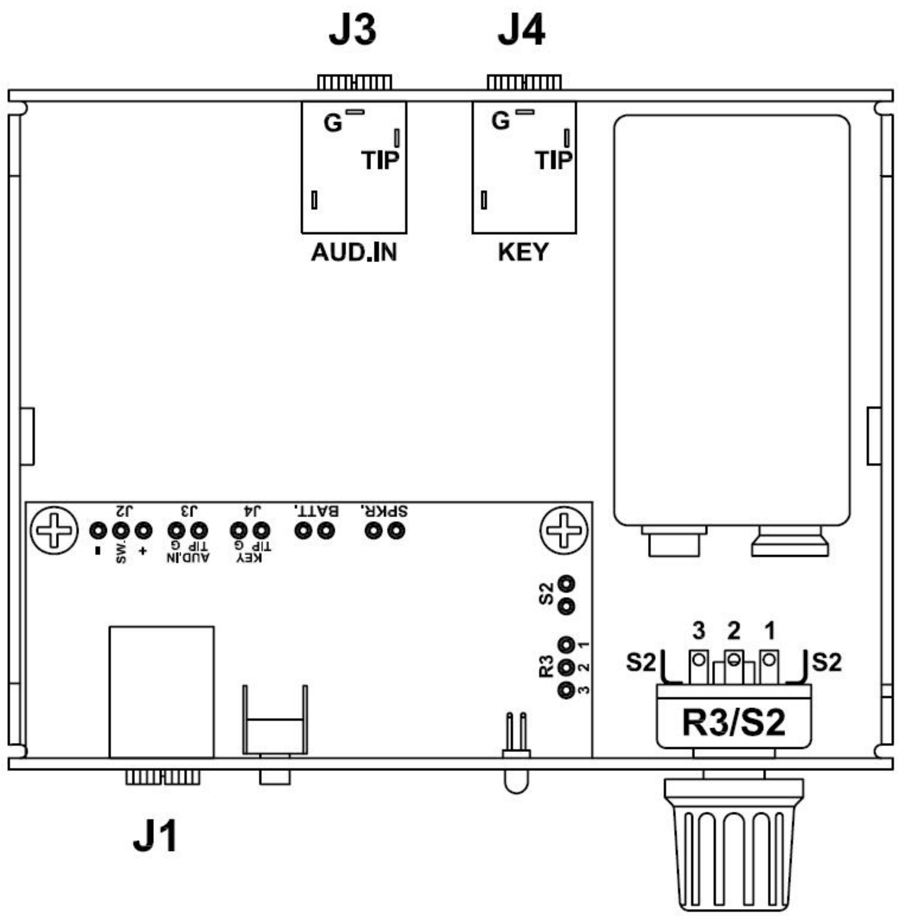
An audio input into J3 should yield amplification to the speaker.

As always, if any problems are encountered, look for the most common problem, poor solder joints.

Next is an incorrectly identified part, and reversed polarity components. Sometimes it is difficult to see your own mistakes, so have another person check it out.

- Next, apply the decals to the chassis as described in Appendix A.

You may now proceed to the mounting of the board to the chassis and final assembly.



- Line up the J1 and the led to the holes in the chassis front and secure the board with threaded nut for J1 and two 4-40 x 1/4” pan head screws for the pcb.
- Mount the potentiometer and tighten the supplied nut and washer. Check to see that none of the potentiometer connections touch the bare chassis. Trim if needed.
- J3 and J4 can be secured with the threaded nuts in the proper holes provided in the rear. A piece of two sided tape may be used under the battery to keep it from moving inside.
- Attach the speaker to the cover using the two clips and 4-40 x 3/8 flat head screws.
- Finally, attach the cover to the chassis base using two 4-40 x 1/4 flat head screws.
- Attach the four rubber feet, and the instrument knob.

This completes the assembly.

General operation notes:

Interconnection to your device makes an assumption that the output and input to and from your device is between ground and the tip of a stereo plug. If your device uses the sleeve instead of the tip, your interconnecting cables will have to be adjusted accordingly.

If your device generates its own sidetone internally, jumper the NST pads.

If your device does not generate its own sidetone internally, do not jumper the NST pads.

Also, by removing the NST internal jumper, you can also use this kit as a code practice oscillator with your paddle. Be sure to turn off when changing jumpers.

The front paddle input connections to the keyer/speaker console are set up for the tip being “dit” and the sleeve to be “dah” on a stereo plug.

Note that the Mute and ST connections are not used. They are part of Steve’s original design and were left for any flexibility.

Keyer Operation

There are five possible functions which are selected using the “Function” Switch. These are:

1. Send message
2. Set code speed
3. Enter and exit Tune Mode
4. Enter store message mode
5. Change from Iambic B to A mode.

Sending messages:

After a short, quick click of the function switch, tap the Dot paddle to send message 1 or tap the Dash paddle to send message 2. Once a message has started to be sent, it can be paused, stopped or set to beacon mode. Note: only message 1 can be used for beacons.

Pause: Close and hold the Dash paddle.
Stop: Close and hold the Dot paddle.

NOTE: these actions will occur after a character currently being sent has finished sending.

Beacon mode:

Click and hold the function button as Message 1 is being sent. The letter “B” will sound from the side tone when the mode is activated. There is a fixed 3 second delay between repeating the message. Closing either paddle during the delay will terminate beacon mode. In addition, message Pause and Stop may be used during the sending of the message.

Change code speed:

A short, quick click of the switch enters change code speed mode. There is a short pause to see if you want to send a message, then letter “S” will be sounded by the side tone.

Closing the Dash paddle will increase the code speed, a dot will sound each time the speed in incremented by 1 wpm.

Closing the Dot paddle will decrease the code speed. Again, a dot will sound each time the speed in decremented by 1 wpm.

At the upper and lower speed limits, a double dot (I) will sound.

The change code speed mode will automatically exit after the paddles have been released for about 1 second.

Tune mode:

Tune mode is used when you want to key the transmitter continuously to say adjust an antenna tuner or make a power output measurement.

To enter Tune mode:

- Click and hold closed the function switch until the letter “T” is sounded by the side tone (about 1 second).
- To key the transmitter on, tap the Dash paddle closed.
- To turn the transmitter off, tap the Dot paddle closed.
- Repeat as needed.
- To exit Tune mode and return to normal operation, click the Function switch.

Entering Messages:

Click and hold the function switch closed until the letter “M” is sounded by the side tone, about 1 second after the tune mode annunciation of “T”.

A message of up to 29 characters (including word spaces) may now be entered via the paddle. If you exceed the maximum character limit, “EM” will sound and you will have to start again, making the message shorter.

If you have a 2X3 call, you won't be able to quite fit a 3x3 CQ into the memory.

“Ideal” timing of 7 dot times for character space and 21 dot times for word spacing is used to determine the completion of a character or word space. To insure a word space in inserted, it is best to pause slightly longer they you would otherwise between words.

Click the Function switch when you are finished entering the message. The message will repeat so you can check for timing errors. If you need to re-enter the message, click the Function button and “EM” will sound.

Since many CW ops then to run their letters together by leaving insufficient space between the end of one letter element group and the start of the next letter, the message may come out quite garbled. It may take several tries and some practice to get the message to record properly.

• If the message was entered correctly, tap the Dot paddle to store the message in location 1 or the Dash paddle to store in location 2. “MS” (message stored) will sound and normal operation will resume.

Selecting Iambic A/B mode:

Click and hold closed the Function switch until the letter “A” or “B” is sent by the side tone, about 3 seconds. If the keyer was in “A” mode, “B” will sound, indicating it has switched to B mode.

With the new Tiny13 chip, the mode selection is stored in EEPROM memory and the selected mode used on power up.

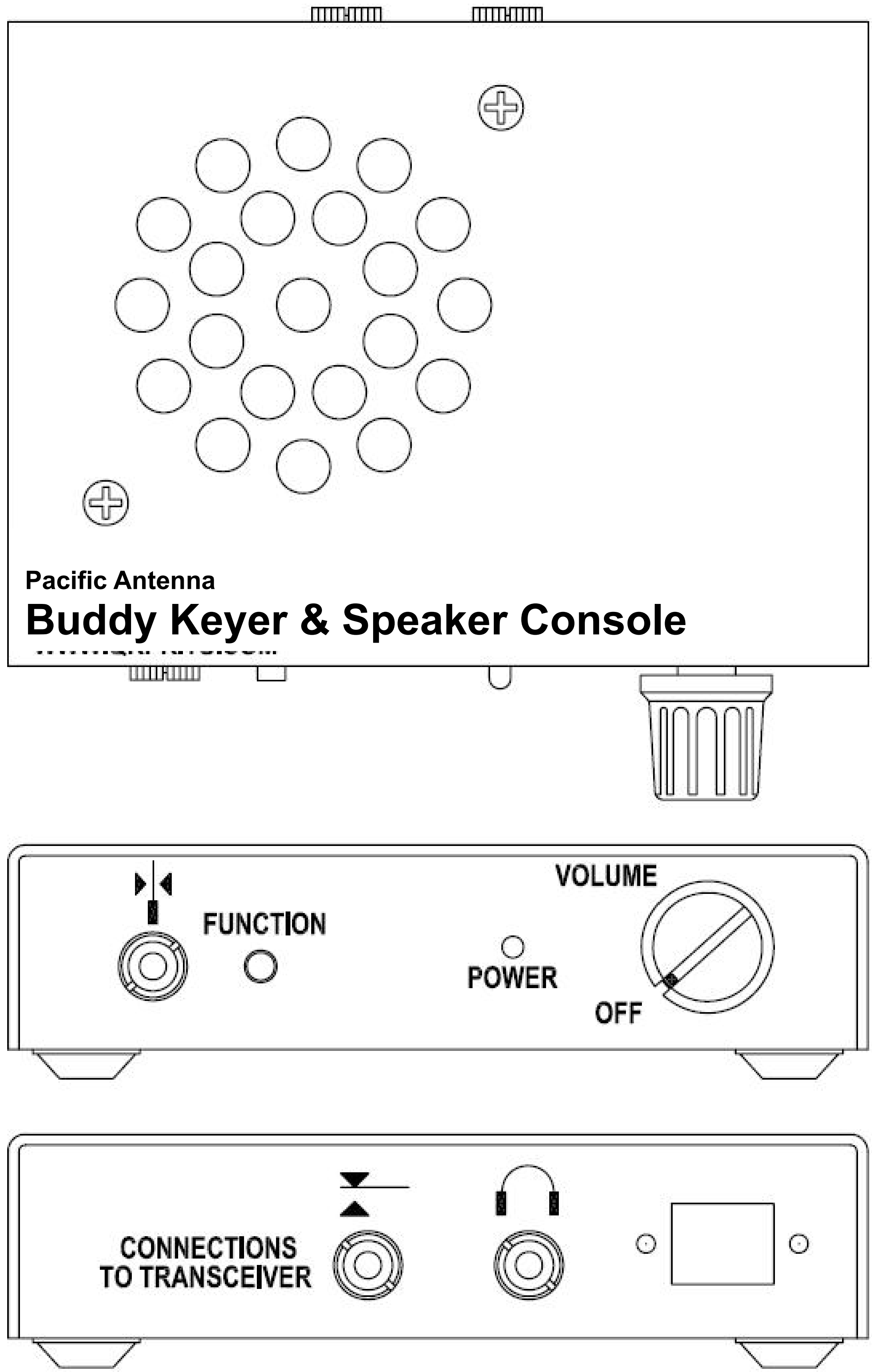
With the old Tiny11 SKC, iambic mode has to be reset each time the chip is powered up if you want to use "A" mode.

We would like to hear from you concerning any impressions or problems with any of our kits.

Please forward your comments to **qrpkits.com@gmail.com**

Notes:

Appendix A: Decal Installation



The decals are applied the same as model decals.

Apply the decals before you mount anything to the chassis.

Cut around each group of text or symbols you wish to apply. It doesn't have to be perfect as the background film is transparent.

Use the above picture to get the correct spacing around the holes and cutouts, as it is very easy to do a great decal installation and have a portion covered up with a knob

Before application, thoroughly clean the surface of the panel to remove any oils or contamination.

We have found that moving the decals into position on bare aluminum chassis is difficult, due to the brushed surface, so we advise pre-coating the chassis with the Krylon clear before applying the decals.

Trim around the decal.

After trimming, place the decal in a bowl of lukewarm water, with a small drop of dish soap to reduce the surface tension, for 10-15 seconds.

Using tweezers, handle carefully to avoid tearing.

Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location.

Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal.

You can slide the decal around to the right position, as it will float slightly on the film of water.

Use a knife point or something sharp to do this.

When in position, hold the edge of the decal with your finger and gently squeegee excess water out from under the decal with a tissue or paper towel.

Work from the center, to both sides. Remove any bubbles by blotting or wiping gently to the sides.

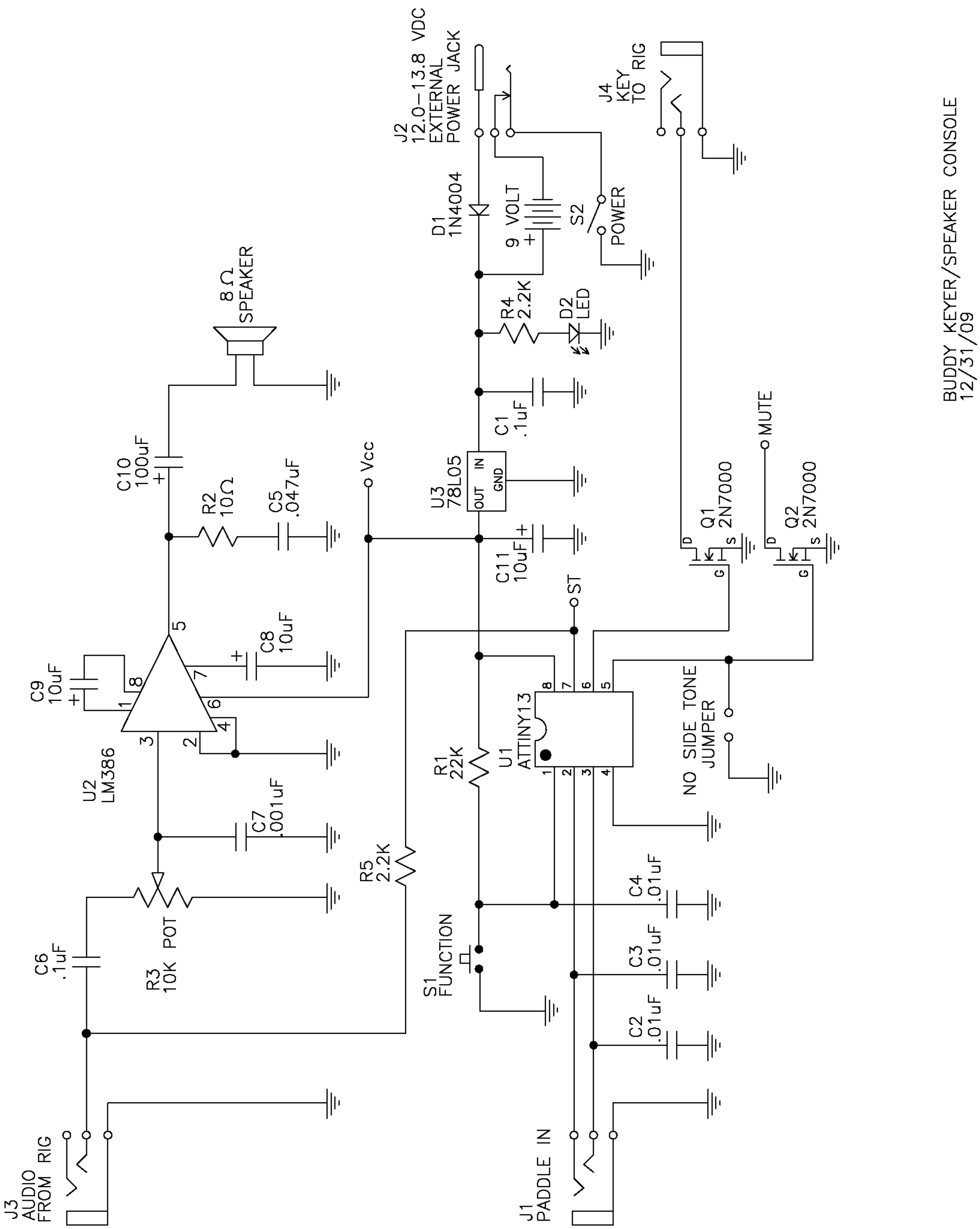
Do this for each decal, and take your time.

Allow to set overnight, or speed drying by placing near a fan for a few of hours.

When dry, spray two **light** coats of matte finish, Krylon or similar clear, protective coating to seal and protect the decals, allowing it to dry between coats.

All decals come with two complete sets, in case you mess one up.

Appendix B: Schematic



If desired, print this, cover with packaging tape, and attach to the bottom to the chassis, as a quick reference for the keyer options. Refer to the keyer instructions mention earlier for expanded explanations.

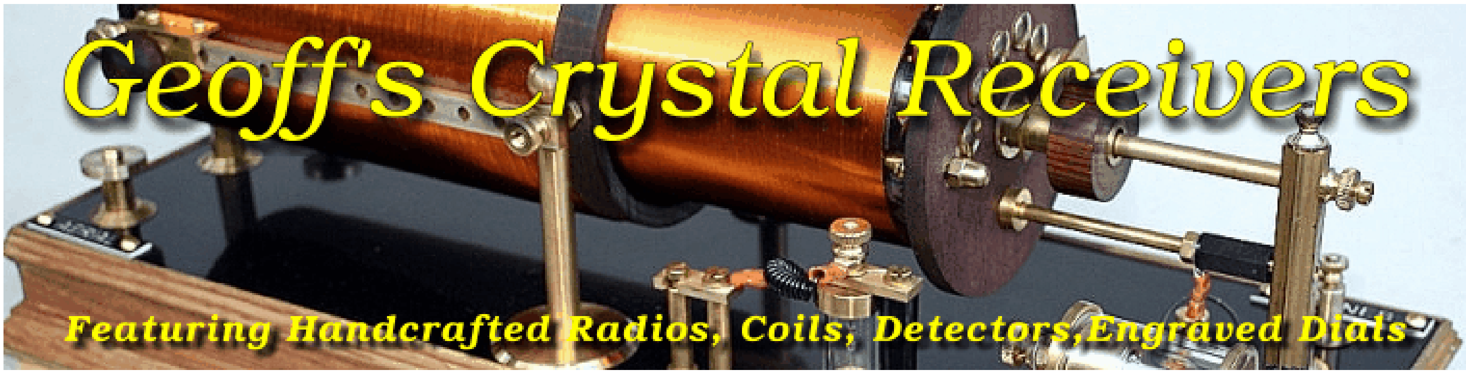
SKC Keyer Options

Change Keyer Speed - Hit "Function" letter "S" is sent, dit to slow, dah to speed up, after a couple of seconds, the letter "I" is sent.

Manual Tune Mode - Hold "function" until "T" is sent. Hit dah for transmit, dit to stop. Hit "Function" to return.

Store up to two 29 Char. Messages - Hold "Function" until "M" is sent. Enter message. Click "function" to hear message and check message. To re-enter meaasge click "Function", "EM" will be sent. Enter message again. To store, tap dit for message location #1, dah for location #2.

Send Message - Hit "function briefly, dit to send message #1, dah to send message #2.



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- Projects

Geoff's Fascinating Loose Coupler Radios
Art and Technical Performance Combined!

Imagine a time in a bygone age when our lives were uncluttered with technology how magical it must have been to hear the first Broadcast Radio Stations on nothing much more than a copper coil of wire and a crystal mineral no battery no power supplies.

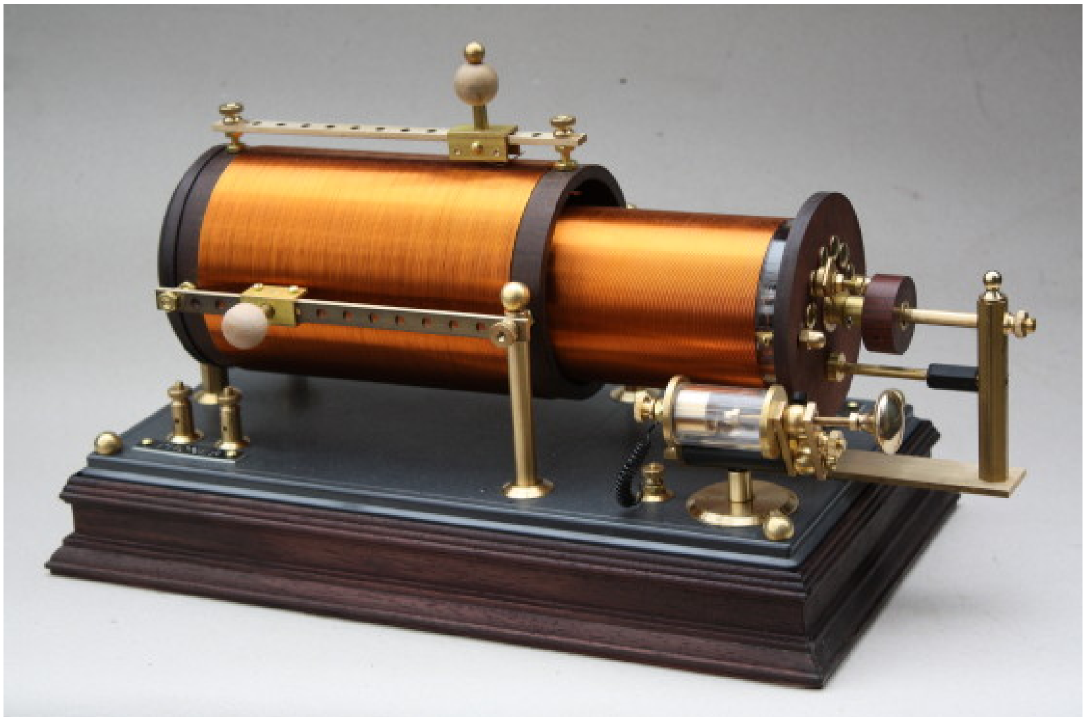
Something that Grandpa made up one Sunday afternoon in his backyard workshop. How was it possible to pull those voices and music from out of thin air. Imagine all the family gathered round in a candle lit room and taking turns to listen to their favorite Radio program on those old Bakelite headphones and the Loose coupler Radio. Hearken back to those times and remember and feel the excitement the whole world was now just at our fingertips.

See my handmade crystal radios.

I can make a custom made radio for you too. Please enquire.

Click on the pictures for a larger view.

Loose Coupler For Long and Medium Wave.



Order Nr. *Loosecoupler MK-1*

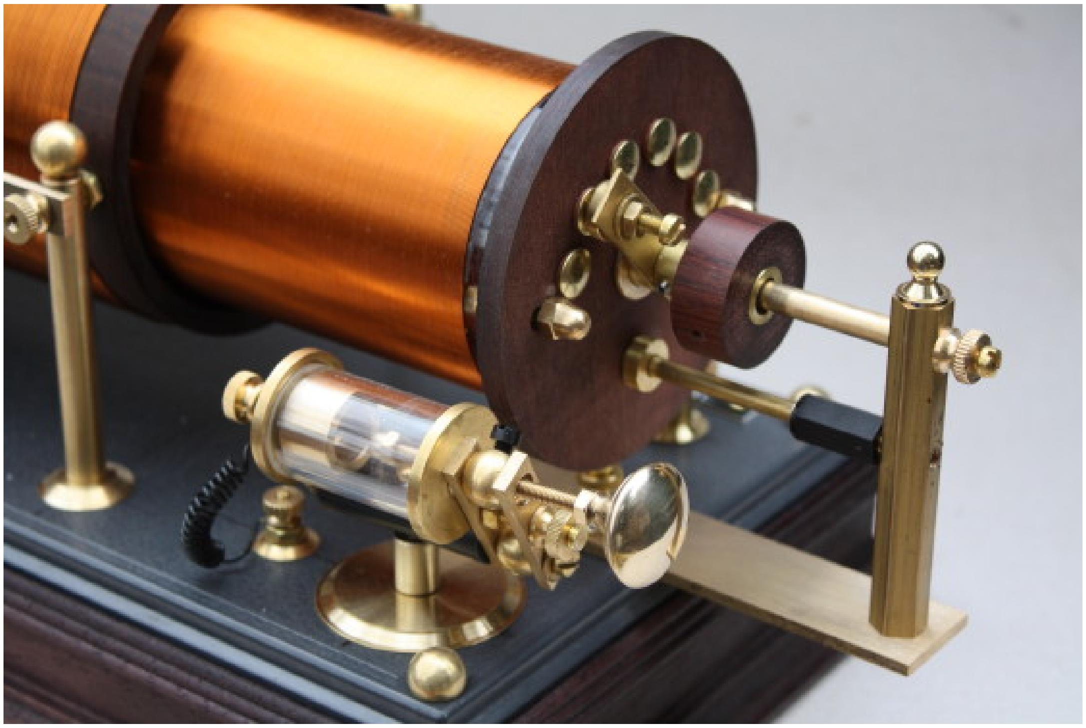
This is a dual slider main coil plus retractable detector winding. The detector winding is switchable. The main winding has slide and stepped positions so you can return to a specific point on the coil.

The main coil is 4 inches diameter and 7 inches long the retractable coil is 3 inches diameter and 6 inches long. The overall set is 13 inches long. I wound the large coil on a modified woodworking lathe and the smaller coil was wound on my AVO machine.

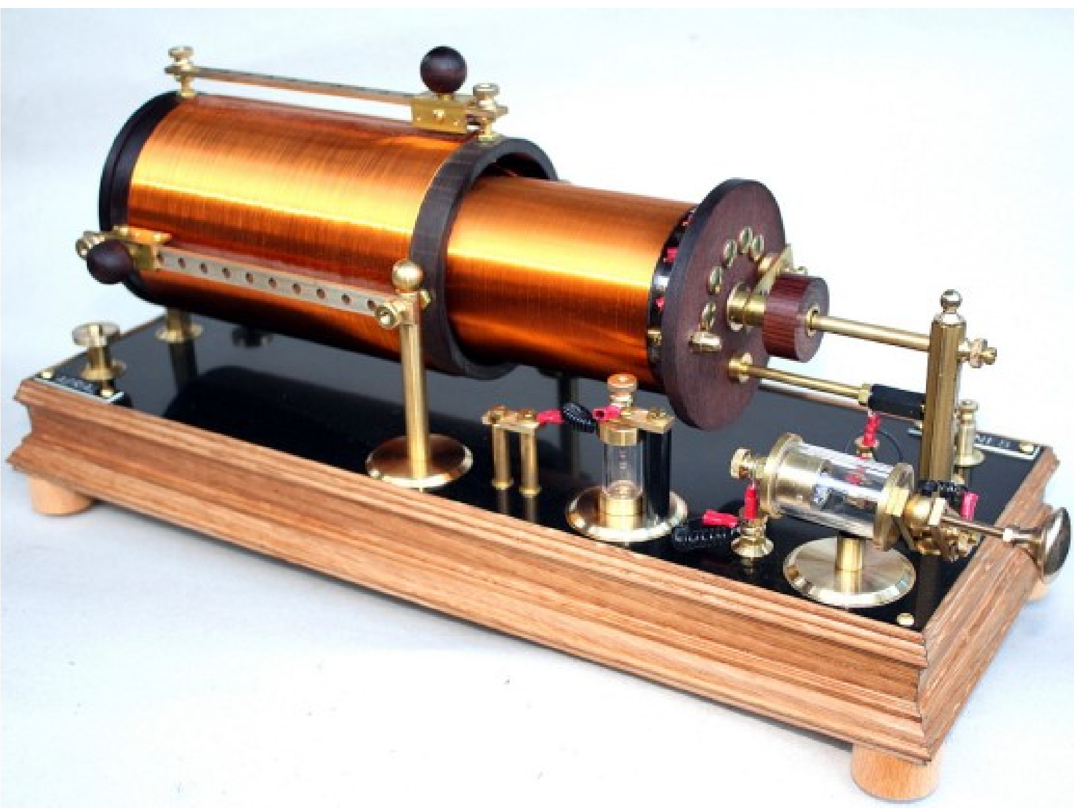
The retractable coil slides along twin brass rails and is very smooth and makes good contact. The spring loaded switch makes a very good contact on the switch studs. There is an internal spring which pulls the contacts together. There are six taps on the coils. I based the design on a 1920's Murdock set from USA.

It was a satisfying craft project but for the amount of work (50 hours). It looks better than it actually works. This particular type of set was dropped by manufacturers in the 1920's for exactly the same reasons. Other simpler sets work possibly better but from a visual point of view these sets are stunning and highly collectable items.

Please click on the photographs for a larger picture of this beautiful wireless receiver.



Loose Coupler For Long and Medium Wave. Mk2'The Gillium'



Order Nr. ***Loosecoupler MK-2***

I had to build another of these sets to experiment with as the last one was sold rather quickly. This time I decided to build it on a longer base so I could add a diode detector as well as the Galena detector plus a simple switch to change from one detector to the other.

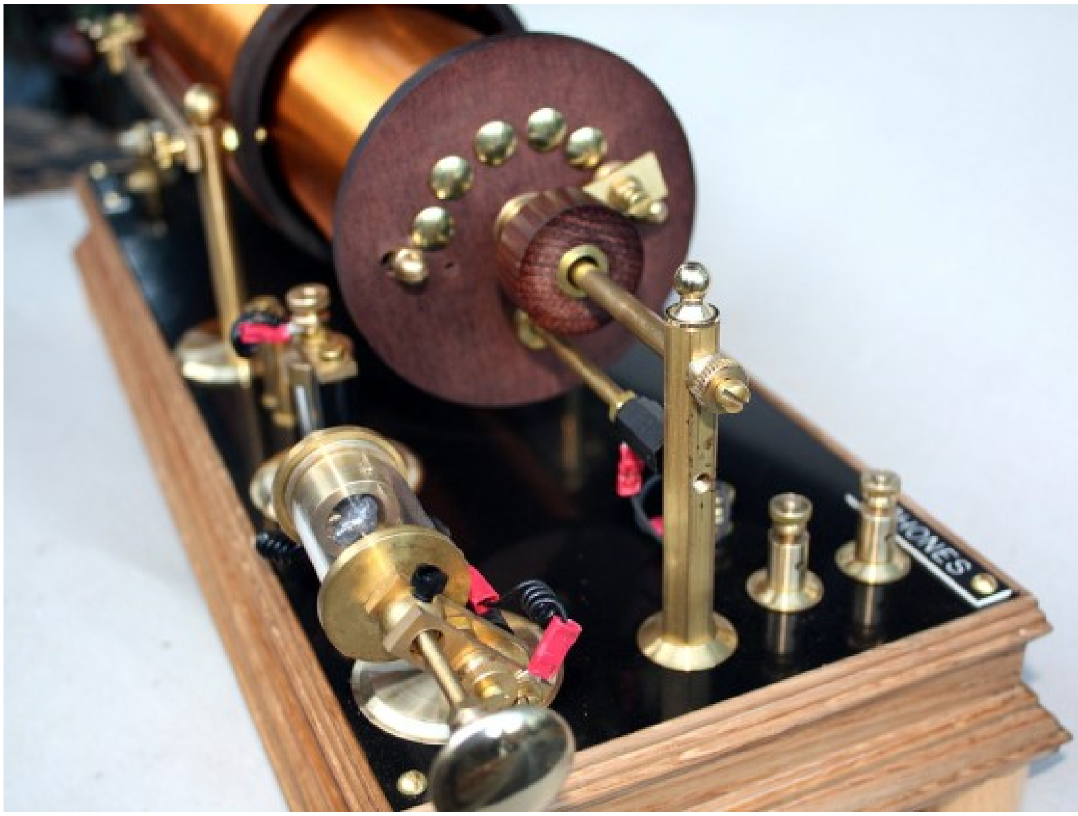
In the days when these sets were firstly made there were no Germanium diodes so I was keen to see how well it worked on the diode. Have I found a long lost secret here as It worked fantastic and was surprisingly loud .I would go as far to say it is the loudest set I have ever made with an enamel wire coil. Radio 4 on Long wave was very strong indeed but is 500KWatts! Almost too loud for easy listening with my Nathaniel Baldwin Armature type phones it was necessary to decouple it a bit to reduce the volume.

I could not find much information on the internet about this type of set before I made one but there were lots of photos of sets from the 1920's no technical information on how well they worked. I guess now it was a well kept secret as they are really superb and worth the effort to wind the big coils and the coupling mechanism.

I had no winding instructions from any technical source so looking at the photos of the Murdock Loose coupler design which was one that I particularly liked esthetically I made a guess at the inductances. The main coil was 4 inch diameter x 6 inch long the inductance was1600uH or 175 turns approximately of .8mm wire and the secondary coil 3 inch diameter and 5 inch long and was wound using .5 mm wire inductance 1800 uH. The secondary coil was wound with taps every inch spacing giving me 6 tapped coils altogether.

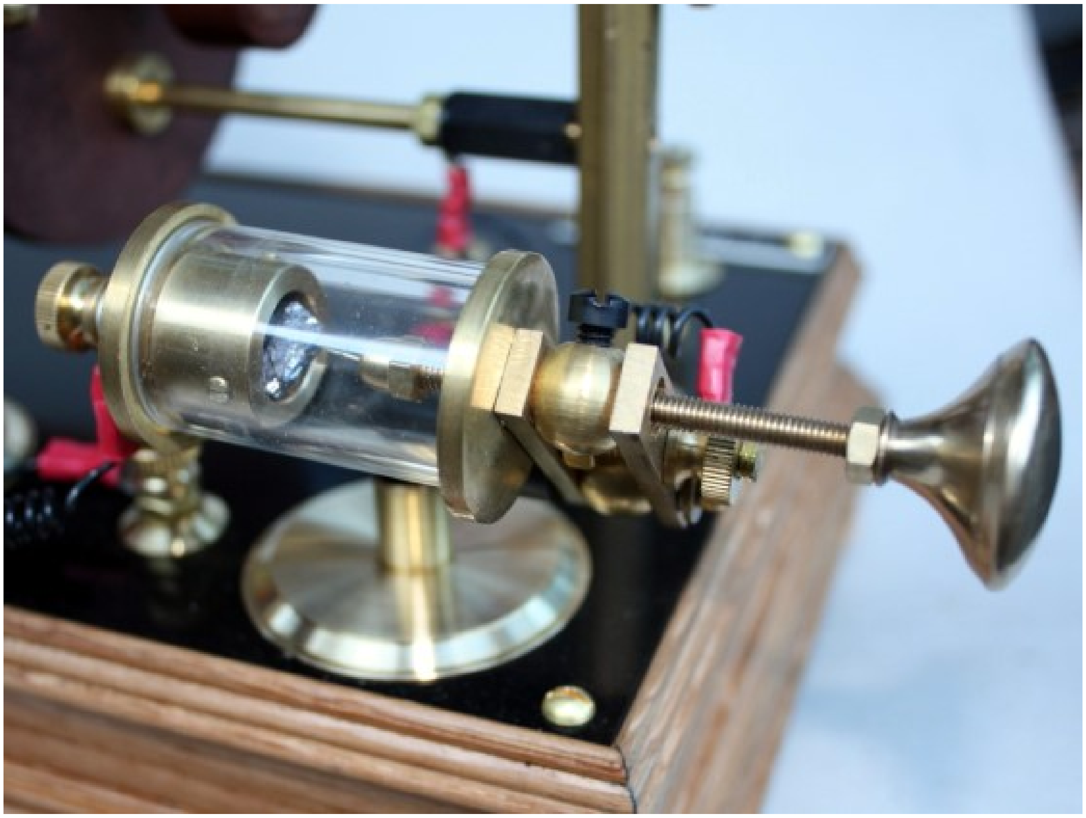
Tuning the set was something completely different to any other set I have made. It appears to tune in three different ways. Firstly by selecting a tapping on the centre switch and then by moving secondary coil into the main coil it would tune into a station and reach a peak volume.

Then if the slider control on the side was set to fully left hand position and the top slider was set to the fully right hand position I could tune long wave and Radio 4 on 198 KHz came in loud and clear. I don't see any way to calibrate this type of radio with a tuning scale but you soon get used to the various settings to find a station. To tune medium wave I moved the lower slider to the right and the selector switch to the anticlockwise position by a couple of positions. Many stations on medium wave could be heard and the selectivity was not at all bad considering there is no capacitor to fine tune the set. It will need a lot more experimenting to fully understand the relationship between sliders coupling and switch, however hats off to the original inventors of this type of radio. They are a very satisfying project to make and to tune round the Airwaves.They look very esthetically pleasing to my eye. A proper Radio ! I must build a MK3.

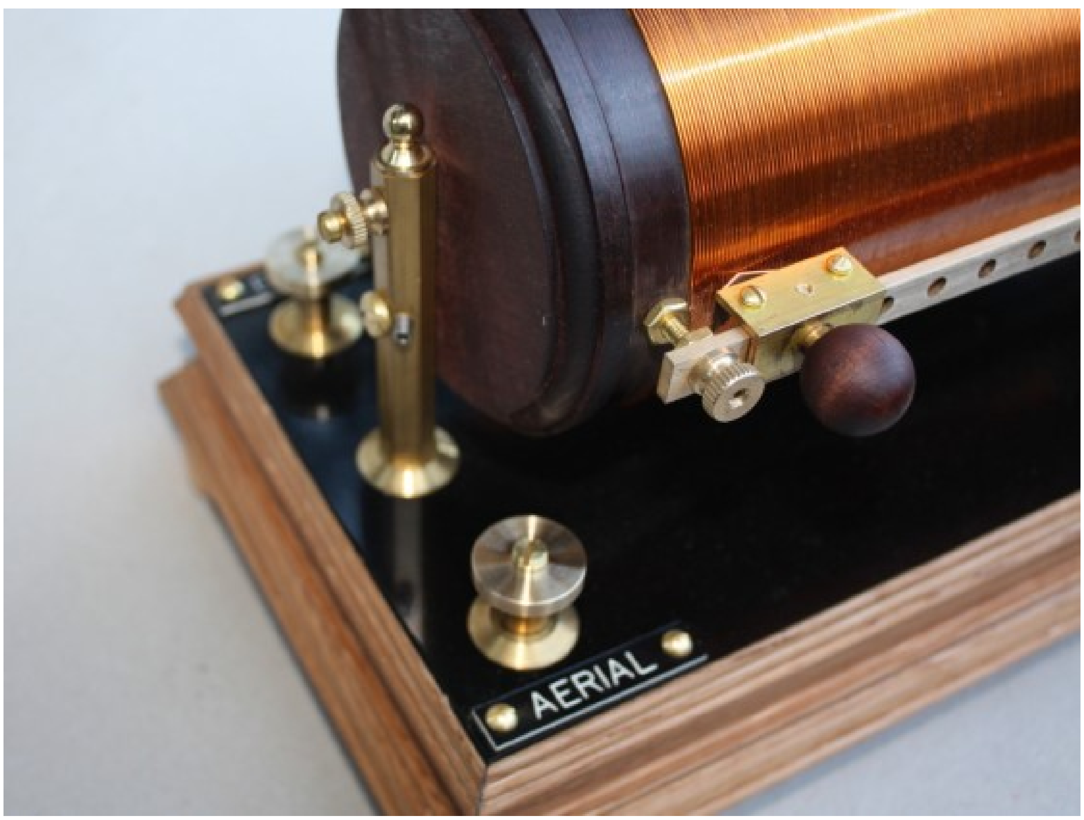


End View

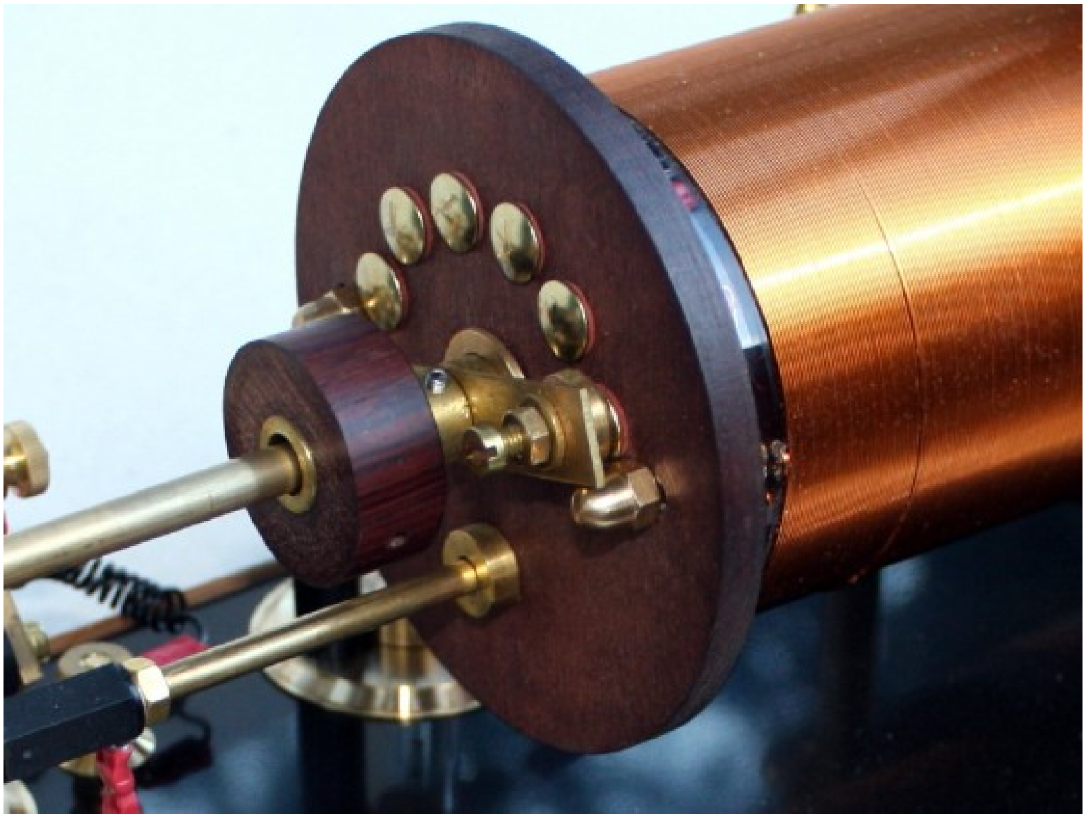
Diode Detector and Selector Switch



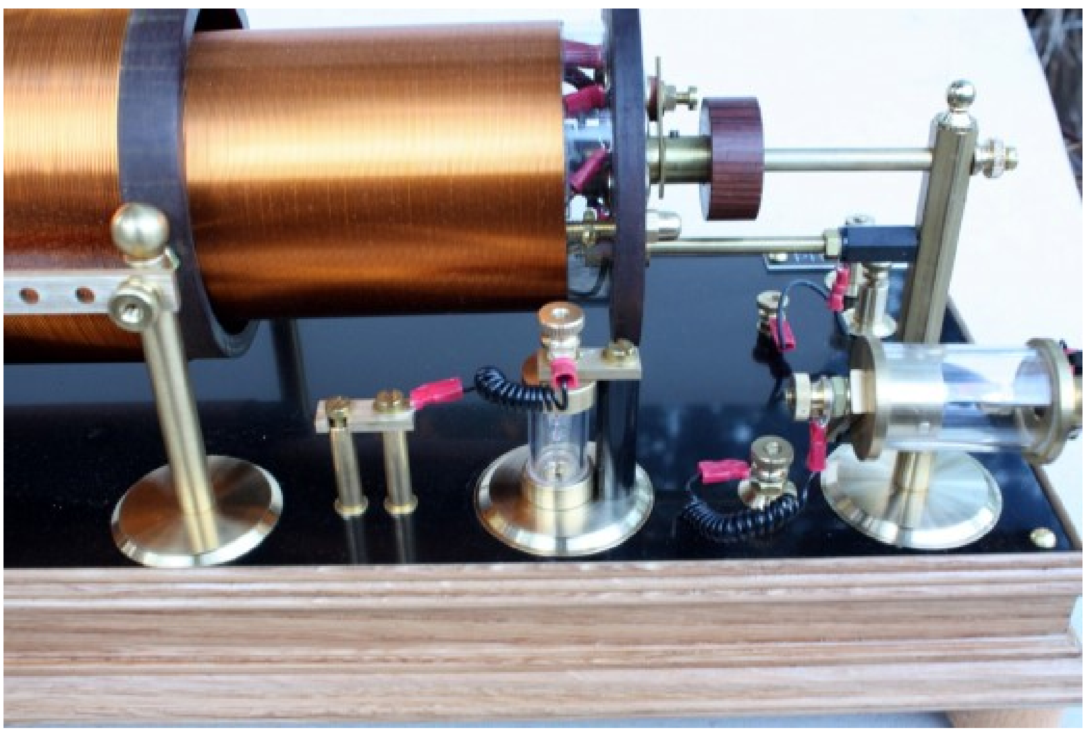
Galena Detector



Slider



Main Selector Switch (Coil taps)



Detectors

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Geometry Aspects and Experimental Results of a Printed Dipole Antenna

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Abstract

Detail experimental measurements of a 2.4 GHz printed dipole antenna for wireless communication systems is presented and discussed. A group of printed dipoles with integrated balun have been designed and constructed on a dielectric substrate. This paper is based on modifications of the known printed dipole architecture. The corresponding printed dipole antennas have differences on their forms that are provided by two essential geometry parameters. The first parameter l is related to the bend on microstrip line that feeds the dipole and the second w corresponds to the form of the dipole's gap. The impact of these parameters on reflection coefficient and radiation pattern of antenna has been investigated. The corresponding measured results indicate that the return loss and radiation pattern of a printed dipole antenna are independent of the w parameter. Instead, variations in the value of the l parameter in the dipole's structure affect the form of the corresponding return loss. These observations are very important and provide interesting considerations on affecting design and construction of antenna elements at frequency range of 2.4 GHz.

Keywords: Printed Dipole, Scattering Parameters, Radiation Pattern

1. Introduction

Modern wireless communications offer higher bit rates and efficient quality of services. The majority of the equipment used today introduces requirements for better performance and lower cost. Antennas with quite small sizes, low profiles and versatile features represent interesting solutions that provide modern wireless applications. The printed dipole antenna with integrated balun is widely used as a radiation element on communication systems because of its omni-directional features, narrowband character and simple structure [1–4]. This type of antenna because of its small size can be integrated on the same PCB with other electronics circuits and devices. For the same reason, it can also be used as element on antenna array architecture. The last feature is very interesting and attractive in MIMO modern wireless systems. This printed dipole architecture offers versatile characteristics for design and implementation of antenna arrays on both ends of a MIMO wireless system.

In the present paper, we will study and discuss the effect of the variation of the two geometrical parameters (l, w) of the printed dipole antenna structure. The first corresponds to a discontinuity on microstrip line of printed dipole and the second is related to the discontinuity in the gap. Details of structure concept and design process are presented in Section 2; the experimental results for return loss and radiation pattern for each of the printed dipoles are presented and discussed in Section 3. The paper concludes in Section 4.

2. Design and Structure Aspects

As mentioned above, the proposed analysis is based on geometrical characteristics of a prototype printed dipole antenna with integrated balun. This kind of printed dipole antenna is considered for use in many applications [1–3]. In our study the geometrical parameters of the printed dipole antenna were modified to achieve better performance in the frequency range of 2.4 GHz. This modified design and the corresponding parameters are shown in Figure 1 while the values summarized in Table 1.

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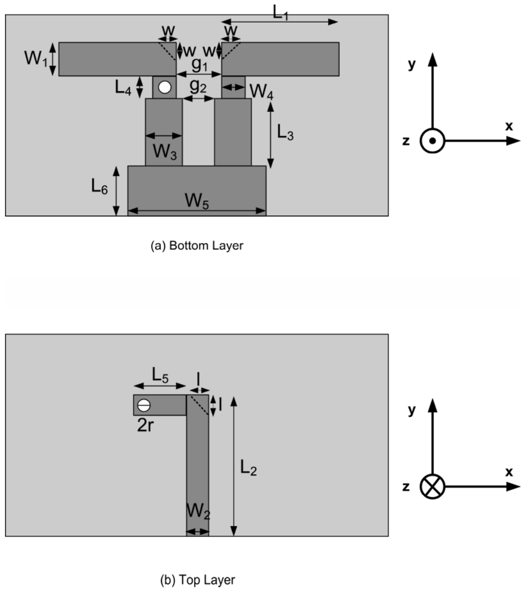

Figure 1. Geometry of printed dipole.

Table 1. Printed dipole dimensions.

Parameter	Values
Dipole strips	L1 = 20.8 mm W1 = 6 mm g1 = 3 mm
Microstrip Balun	L2 = 32 mm L3 = 16 mm L4 = 3 mm L5 = 3 mm W2 = 2 mm W3 = 5 mm W4 = 3 mm g2 = 1 mm
Via radius	r = 0.375 mm
Ground plane	L6 = 12 mm W5 = 17 mm
Side of microstrip bend	l variable (0 mm – 3 mm)
Side of dipole's arms in the gap	w variable (0 mm – 3 mm)

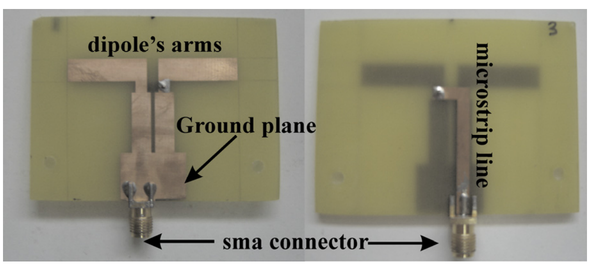

Figure 2. Prototype printed dipole antenna: Top Layer (left) –Bottom Layer (right).

An Fr-4 substrate with thickness of 1.5 mm and permittivity ε_r =4.4 has been used for the fabrication of the dipoles. Figure 2 shows the top and bottom layer for the one of them. It also presents the dipole's arms and gap, the balun, the ground plane and the microstrip line that interface the dipole with the coaxial feed line via sma connector.

From this Figure, we can also see the right angle at the microstrip line and the other two right angles at the dipole's gap. It is known that the presence of right angles in conductors cause discontinuities that leads to degradation in circuit performance [5]. Microwave theory suggests that these angles introduce parasitic reactances which can lead to phase and amplitude errors, input and output mismatch and possibly spurious coupling [5–7]. In order to reduce this effect it is proposed to modify these discontinuities directly, by mitering the conductor. Our investigation and the experimental measurements show the effect of mitering these discontinuities. At first, a prototype printed dipole antenna with unaffected geometrical parameters has been designed and constructed. Secondly, we constructed and measured six different printed dipoles. Three of them had *w = 0 mm* and different *l* values (1 mm, 2 mm, 3 mm) and the other three dipoles had *l = 0 mm* and different values of *w* (1 mm, 2 mm, 3 mm). All these seven dipoles we constructed, the unaffected one and the mitered ones were measured in an anechoic environment. Figures 3 and 4 show a printed dipole for *l = 2 mm* and *w = 0* mm and for *l = 0 mm* and *w = 3 mm*, respectively. The aim of this study is to investigate the return loss coefficient and radiation pattern in each of these seven dipole's forms. The next section discusses the obtained results and presents the significant observations.

3. Results and Discussion

The return loss of the prototype dipole and the six different modified printed dipole antenna we constructed are measured using a Network Analyzer. These results are shown in two Figures. The first (Figure 5) corresponds to *l* parameter's variations keeping the *w* parameter equal to zero. The second (Figure 6) shows the return loss curves where *w* parameter varies but the *l* parameter equals to zero. In both figures we can see the return loss curve that belongs to the prototype printed dipole (*l* and *w equal to 0 mm*).

From these curves, it seems that this dipole antenna design has a resonance point at 2.4 GHz with 500 MHz –

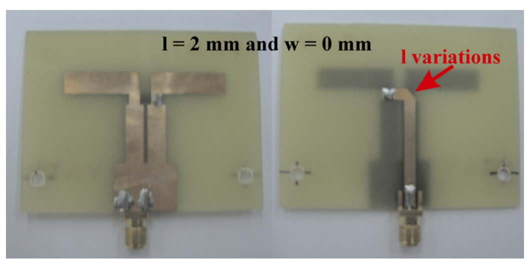

Figure 3. Printed dipole antenna for *l = 2 mm* and *w = 0 mm* Top Layer (left) – Bottom Layer (right).

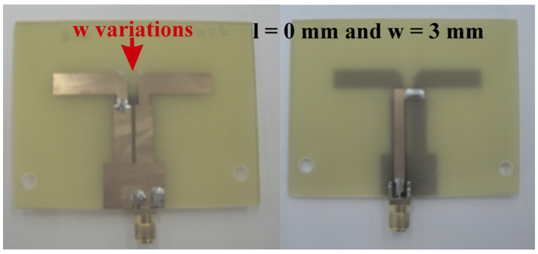

Figure 4. Printed dipole antenna for *l = 0 mm* and *w = 3 mm* Top Layer (left) – Bottom Layer (right).

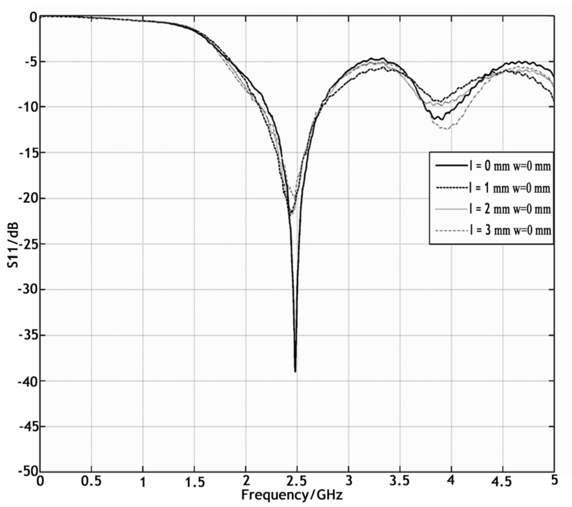

Figure 5. Measured return loss of printed dipole for each value of *l* parameter and *w = 0* mm.

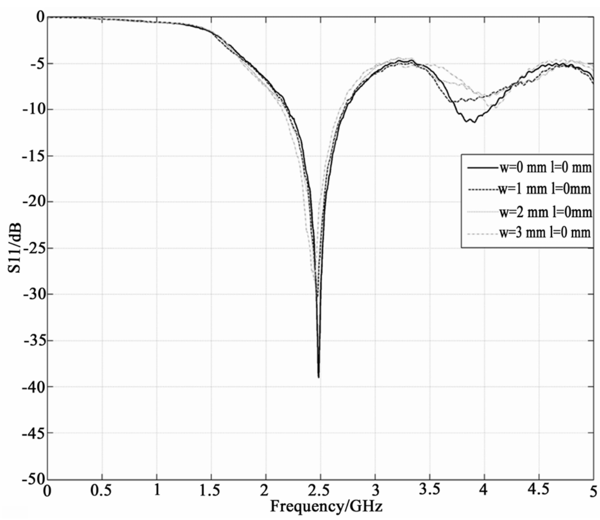

Figure 6. Measured return loss of printed dipole for each value of *w* parameter and *l = 0 mm*.

10 dB bandwidth. The last frequency range has center frequency close to 2.4 GHz which is the frequency value that the return loss is minimized. For these frequencies the corresponding values of return loss are smaller or equal to -10 dB. From Figure 5, it is obvious that as the value of *l* parameter increases, the form of the corresponding return loss curve changes and becomes more flat at the resonance frequency range. On the other hand, the value of *w* parameter does not affect the form of the return loss curve. Each of these seven forms of printed dipole antenna has quite similar return loss curves and introduces narrowband operation at the frequency range of 2.4 GHz. Moreover, for a wireless application that requires design and construction of many identical printed dipoles, it is recommended to choose *l* parameter equals to *2 mm* and *w* parameter equals to *0 mm* for better performance. As it can be seen from Figure 5 the above investigation ensures that the printed dipole antennas will have quite identical return loss curves and performance as elements in an antenna array configuration.

For deeper analysis on this topic, experimental measurements on radiation pattern of these antennas have also been made. Measurements were carried out in a RF anechoic chamber using a calibrated measuring system. In particular, Figure 7 shows the measurements of radiation pattern in E- plane and in H – plane for each dipole

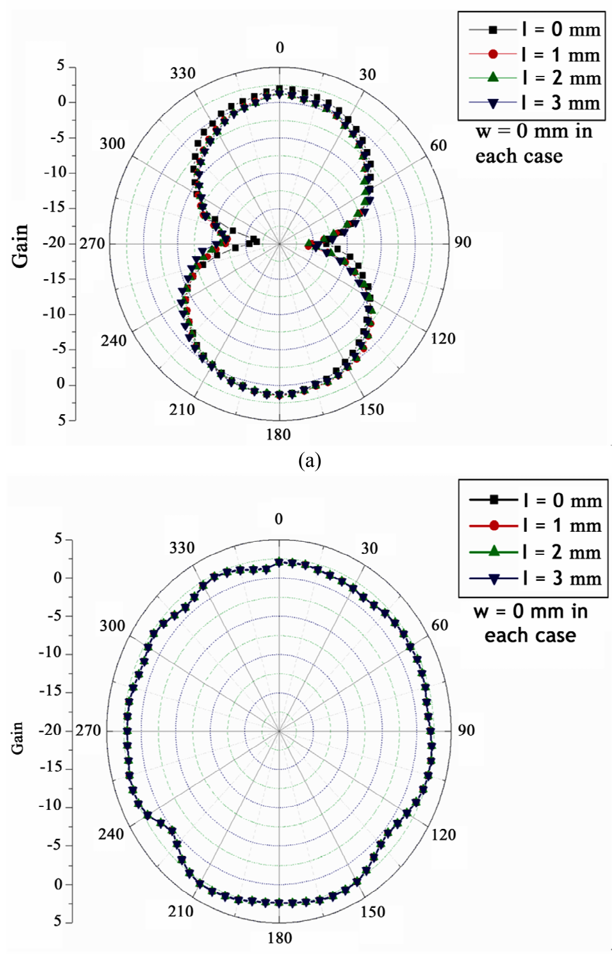

Figure 7. Radiation pattern of dipole for each value of *l* parameter (a) E – plane, (b) H -plane.

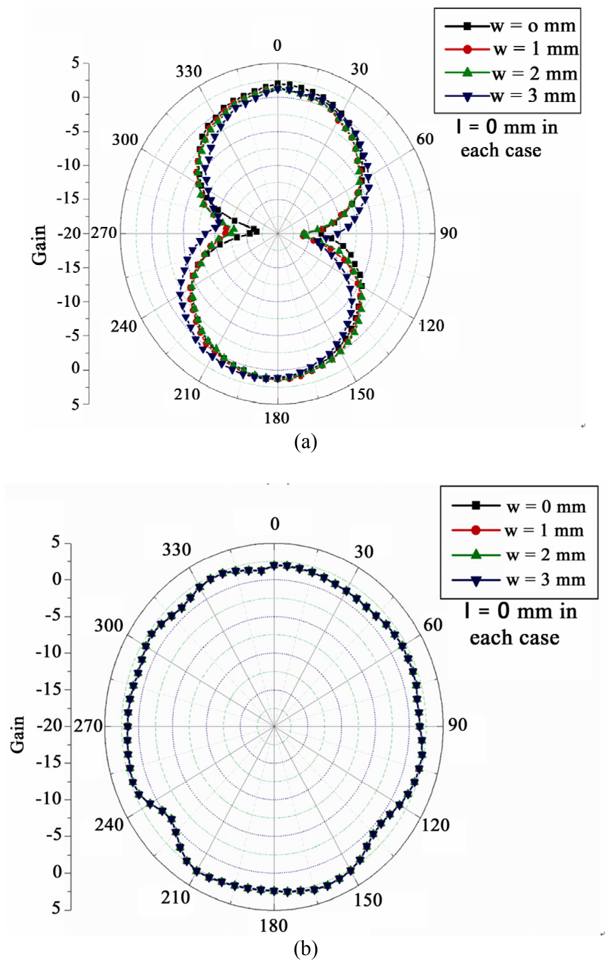

Figure 8. Radiation pattern of dipole for each value of *w* parameter (a) E – plane, (b) H – plane.

with *w* parameter equals to 0 mm and *l* parameter equals to integer values that ranging from *0 mm* to *3 mm*,. Figure 8 shows the corresponding results for each dipole with *l* parameter equals to *0 mm* and *w* parameter's integer values ranging from *0 mm* to *3 mm*. All these dipole structures introduce radiation characteristics that correspond to a fundamental dipole antenna [6,7]. Each of them has a measured peak gain that equals to quite 2 dBi and introduces omni-directional features. Quite small variations on these curves are on the limits of measurements' accuracy. For this reason, it can be observed that the radiation characteristics of the printed dipole antenna are not affected by the variations on *l* and *w* geometrical parameters. Therefore, the radiation diagrams of them are independent of the *l* and *w* parameters.

4. Conclusions

A number of printed dipole antennas with integrated balun are constructed and studied in terms of return loss and radiation pattern. Each of them has a defined form and geometry. Starting from a dipole antenna we mitered the angles introducing the parameters *l* and *w* that we varied. Experimental measurements on return loss provide the obtained results. These are quite similar and also introduce a resonance point at frequency range of 2.4 GHz with narrow resonance bandwidth. The form of this resonance range is affected only by the *l* parameter. The radiation pattern of these dipoles is also investigated. The corresponding radiation diagrams are independent of these geometrical parameters (*l*, *w*) and are similar to that of the fundamental dipole. These observations on printed dipole architecture are very crucial for wireless communication engineering and antenna design. This is because they introduce the ability of constructing a group of identical dipoles choosing an appropriate value of *l* parameter (*l =2 mm*) with quite identical resonance and radiation characteristics.

5. Acknowledgment

This research project (PENED) is co-financed by E.U.-European Social Fund (80%) and the Greek Ministry of Development-GSRT (20%).

6. References

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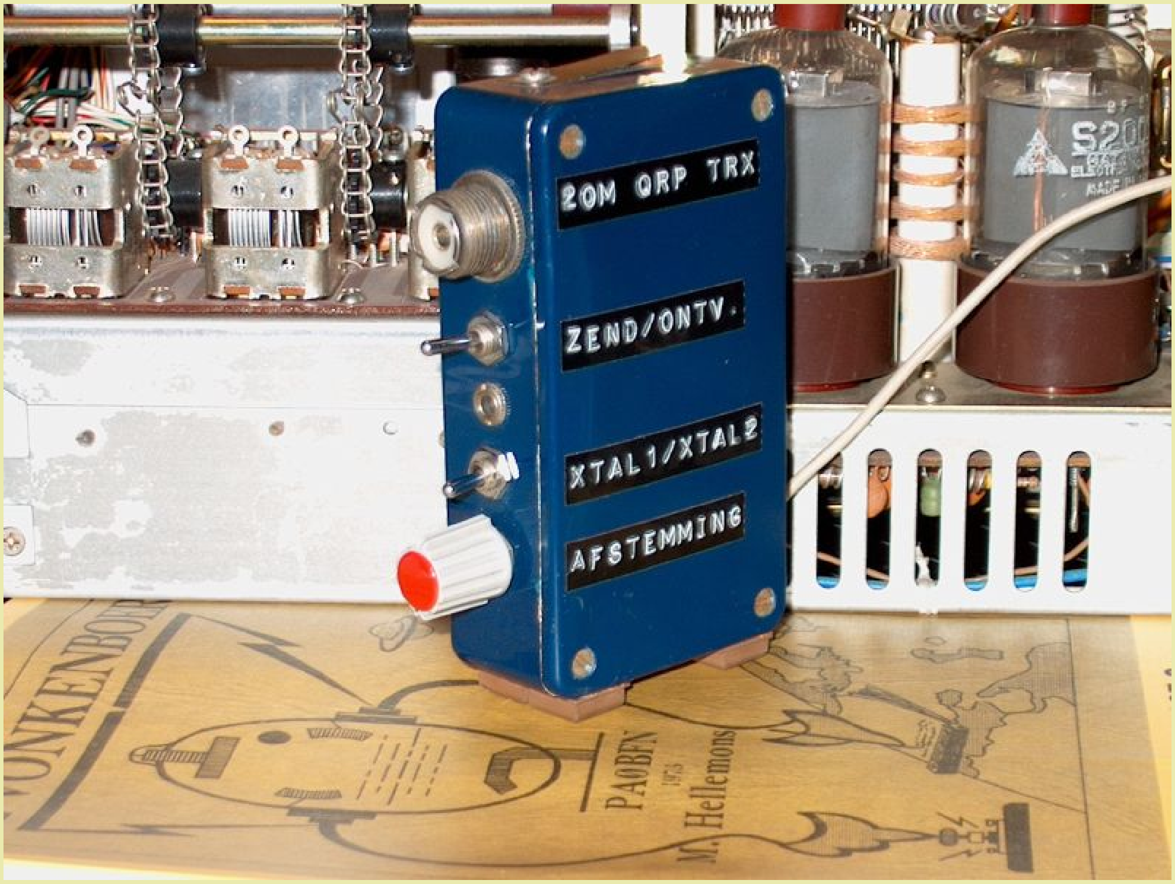
MY FIRST QRP RIG "THE BAREFOOTER"

(1979)

KLIK HIER VOOR DE NEDERLANDSE VERSIE



An ultra portable QRP CW-transceiver for 20 meter.

Holidays in Norway and Sweden with the simple QRP transceiver!
When I found the design, I could not believe that it was possible to make QSO's with it as its simplicity is such a huge contrast with the usual amateur transceivers with high power, superhet receiver and other complex circuits. But it should be a very nice experiment to take such a simple transceiver with me on holidays to Norway and Sweden!
Within two weeks this 20m QRP rig was ready to take with me on holidays to Norway and Sweden. And the results were astonishing! Almost every day it was possible to make a QSO with a radio amateur living nearby my home QTH. With ease, also a lot of other QSO's were made. Although I was just a starting radio amateur and the direct conversion receiver does not have much selectivity, I did not have any difficulties with the reception of the other station with a power of 100 watt. But when it should have been a QRP station, that would certainly be a problem! Unbelievable that you can make a QSO over such a distance with such simple equipment. And that while you are barefoot on a very isolated place in the magnificent nature. With nothing more than a very simple antenna and the Barefooter QRP rig with 4 transistors and 1 IC and two batteries!
As this simple rig worked much better than expected, I also made a two band version for 40 and 20m. And when the 30 meter band became available, also a version for this band was made.

Camping and working QRP portable with the simple Barefooter QRP transceiver at such nice places in nature!
What do you want more...

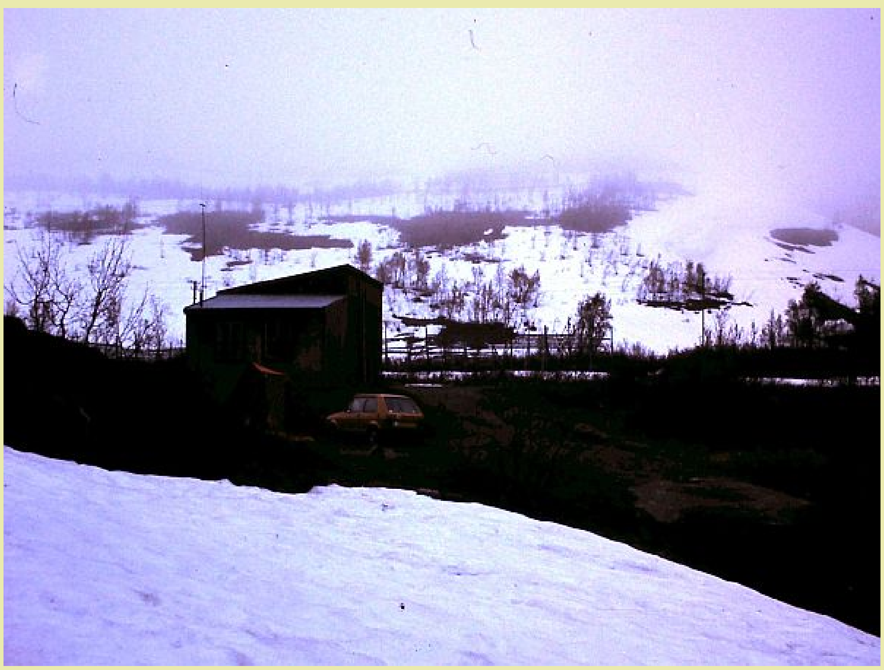
A portable station on bare feet!
Due to the barefooter QRP transceiver I did walk barefoot in the woods and in the snow during working portable and when camping in the free nature! As on a camping in the beginning of our holidays, I showed my small QRP transceiver with Barefoot Power to a few boys. One of them told that he did like to walk barefoot in the woods and even in the snow when it is not colder than -3C. And we got a nice idea. Back to basic! A very primitive portable station on bare feet without thick walking shoes! Which nice places in nature can you reach with just your bare feet? And can you make QSO's over there with that very simple transceiver and a very simple antenna? Exciting and challenging!

Portable on bare feet in the snow!

Portable in the woods
For the first time camping in the deserted woods instead of a safe camping! Nobody to see, all alone. Exciting! The only contact with the outer world is possile with the portable station on bare feet! Great! For the first time on bare feet! How cold! Horrible, although... I did feel the branches and stones quite well, but they were much to our suprise not too painful. First put down your toes, then your heels, that does walk already much better! During half an hour I did walk barefoot in the woods without real problems and I did find a good place to work portable.
Hanging up the antenna was so difficult that I even forgot that I did go barefoot in the woods! As branches and trees are very suitable to hang up an antenna, but they are also in the way when pulling up the antenna! The simple transceiver was connected to the antenna and batteries and a wonderful orchestra of CW signals could be heard. Making the QSO with The Netherlands was often difficult, not only because of the bad radiation in the woods, but also due to the many stations on- and nearby the frequency. When after a few repetitions, all the information was exchanged, I really had a feeling of victory!
Walking barefoot in the woods was much nicer, challenging and more active than with shoes! It was a great new experience and very nice to feel where you are walking! Despite the cold, sharp branches and stones, I did walk barefoot in nature during the whole evening. And that was so nice, that I would do that more often! Portable in the woods, on bare feet it was nuch nicer, challenging and more active than with shoes on! Although, sometimes a thorn had to be removed...

Of course I got cold bare feet and ice cold red toes while working portable in the snow!

Portable in the snow!
And then we came in the north in a rough, cold winterlandscape! It was a huge challenge to camp and to work portable here on bare feet! Thick winter clothes, gloves and ... barefoot in this freezing cold winter landscape! Unbearable cold, I thought that I was dying! But quite soon that unbearable feeling disappeared. Then it suddenly felt as if I could walk barefoot to the North Pole. Setting up the vertical antenna on the ice with snow was difficult. Funny those cold red bare feet in the white snow and on the ice! The batteries were kept warm under my clothes. And... three normal standard QSO's were made with 57 reports. At the end of the third QSO the vertical antenna did fall over. I did walk another hour barefoot on the ice and then it was time to go to the warm tent. My bare feet had survived the cold!!!



And then we came in the north in a rough, cold winterlandscape!
It was a huge challenge to camp and work portable here on bare feet!

Portable on the snowy mountain top!
Sometimes I did even totally forget that I did walk barefoot in the snow! As after a few times, getting used to the cold became much easier and then I did not understand anymore why that was so unbearable cold the first times! And then it was time for the sked. I wanted to climb the snowy mountain slope on my bare feet. And... with success!!! The vertical antenna did perform excellent! Good signals, not a word was missed. Only at the end of the QSO a QRO station came suddenly on the frequency. You cannot blame him for that, at that time, everyone was working with at least 100 watts and there were almost no weak QRP signals. Incredible! Far from home while standing barefoot with ice cold red toes in the snow it was very easy to make a QSO to The Netherlands with the simple battery-operated QRP transceiver and homemade antenna! Portable in the snow, on bare feet it was much nicer, more challenging and more active than with shoes on! Although, in the beginning really unbearable cold, later not anymore! My bare feet and toes became really

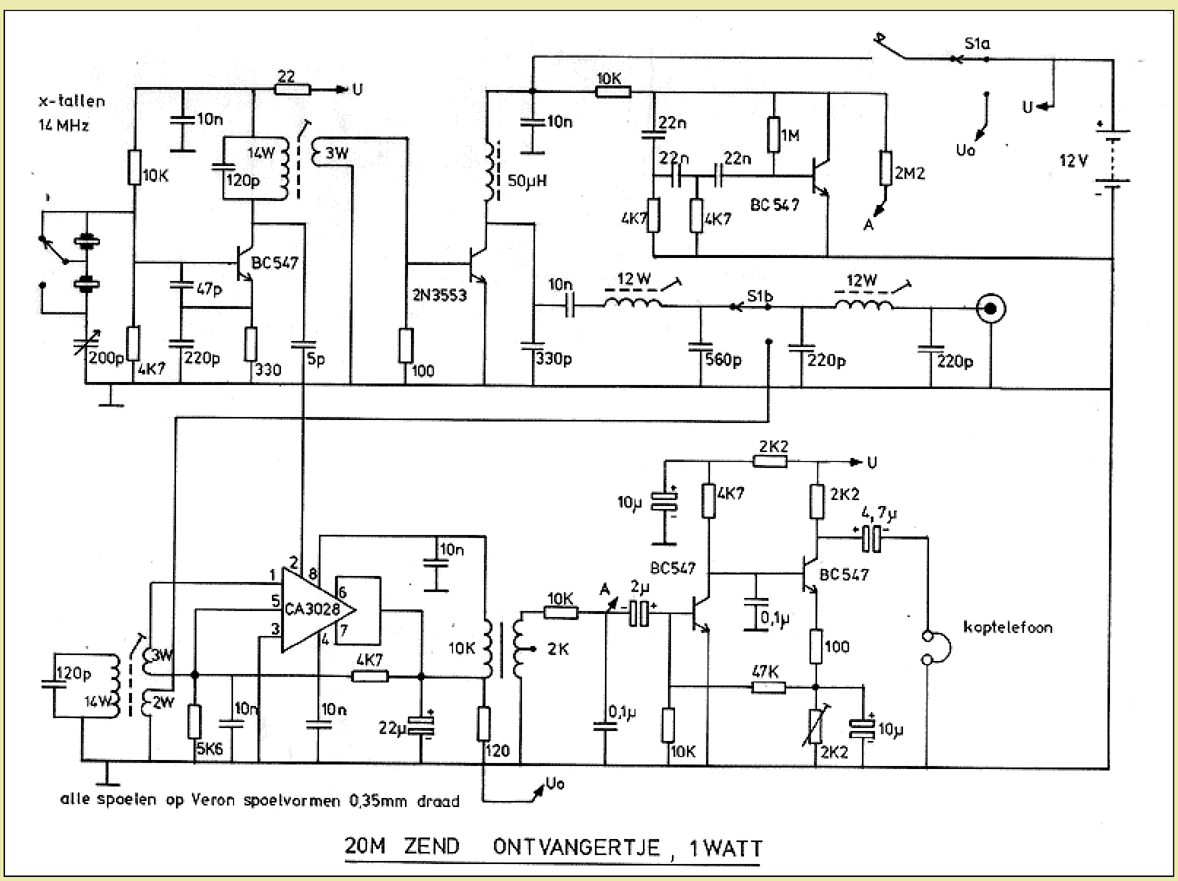
freezing cold in the snow! But it was fun to experience how my bare feet were still able to adapt to the cold. Energy was flowing in my bare feet and therefore also in my body. And on bare feet I could walk through the melting water to work portable somewhere!

Barefoot in the snow during holidays in Norway and Sweden.
Unusual and ice cold in the beginning but funny and nice later.

Beautiful holidays!
Holidays in Norway and Sweden, what a difference with the crowded campings, bars, restaurants and souvenir shops during my other holidays! Walking with thick walking shoes but also barefoot in the free nature without barbed wire and signs for forbidden access. Barefoot for the challenge and the back to nature sensation. To feel with your bare feet, we modern people do not do that anymore!
Nobody to see, a whole forest for us! Pure freedom and life in nature, a great experience. Camping barefoot on very isolated places in the nature, the huge forests and even in the snow was very special. Without luxurious amenities, with water from the stream. That gives an unknown sense of freedom, simplicity, back to basics and a great closeness to nature. There are many good and spacious campings where we were going so now and then to take a shower. But camping in the free nature is much nicer of course!

MY FIRST QRP RIG

The design is based on an article in the book Solid State Design for the Radio Amateur
In fact I do not need to explain everything in detail, just look at the schematic diagram and you will recognize most items. The VXO is used as the local oscillator for the direct conversion receiver and drives the final amplifier when transmitting.



Circuit diagram, sorry for the Dutch language.
big diagram

Mixer
The mixer is an old chip, the CA3028. There are better and cheaper one's like the NE612. As the mixer is not balanced, the receiver is sensitive for AM detection of strong broadcast stations.

LF amplifier
The coupling between the two transistor LF amplifier and the mixer is via a LF transformer. And that is a problem if you use the rig nearby power lines or transformers, a loud 50 Hz hum is heard. I took a LF driver transformer of a balanced final LF amplifier from an old transistor radio.
The two transistor LF amplifier drives the headphones. Connect both earpieces in series instead of in parallel for much more audio output.
During transmission, the side tone generator is coupled via the 2M2 resistor (select the value for the side tone level you want to have) to the LF amplifier.
Although there is not so much selectivity, the receiver sounds good and I always listened to it with pleasure. The 2k2 potentiometer is for the battery-empty indication. Connect the rig to the minimum supply voltage. While transmitting, adjust the potentiometer so that the side tone disappears.

VXO
The VXO frequency is varied by a simple variable mica capacitor. Via the 5 pFcapacitor, the VXO signal is fed to the mixer.
I used two crystals: 14045 and 14060 kHz, but of course you can use any frequency you like.
For the two band version, the 120 pF capacitor is removed and the tuneable coil is replaced by a FT37-43 ferrite core (same windings) and I use only one crystal per band.

Transmitter part
The VXO signal is amplified to 1 watt by a transistor 2N3553. The output is filtered in two pi sections. Why is switch S1b in the middle of the filter instead of at the end? I really do not know. In the two band version I used two 5 pole filters and switch S1b at the end of the filters. Solder a 100 pF capacitor between the collector and emitter of the 2N3553 for stability reasons.

The inside view, all "Simple QRP" technology.

Notes
The CW key is a simple microswitch. When you see the photo's, you do not need a further explanation. In the 2 band version, I used an extra PNP transistor, so that the key is connected to ground.
The two earpieces of the headphone are connected in series instead of in parallel for more audio.
For the two band version, I also added a 1k potentiometer between S1b and the receiver for RF volume control.

Performance
I had a lot of fun with this rig and used it during holidays under all kinds of conditions. It always worked good!
The receiver is sensitive enough, some AM detection of strong broadcast stations is possible, the audio transformer gave problems when camping close to overhead power lines, there is no volume control, but it was real fun to use this rig. The antenna was a dipole between trees or as inverted V, the middle at 4 meters using a 5m fishing rod as a support. I also used a vertical (vertical wire mounted to the vertical fishing rod and 6 radials of 2 m length).
The rig was also used in the shack with a long wire antenna and a tuning unit. Many perfect QSO's are made, even long chats.
I also designed a new version, the 4 band HappyHoliday trx, you can find a description of it somewhere on this site.

RX current: 30 mA (quite high)
Transmit power: 0.6 W at 9 V; 1.5 W at 12 V
Harmonic suppression: Yes!

LICENCE
for
Radio Amateurs

No. ....

In accordance with current regulations pertaining to Licences for Radio Amateurs,

Hoekstra Onno Hans

is hereby authorized to operate a Transmitter of A Class in the following premises:

Mobile Ford Escort 76-JF-43

The registered call sign of the Station is P A 2 0 H H / T F
The licence-holder shall, in his capacity as such, act completely in accordance with the current provisions of the Laws and Regulations pertaining thereto.

This Licence aquires validity as soon as the confirmation of the Radio Inspectorate of the Post and Telegraph Administration has been obtained. It's period of validity is in accordance with the provisions of the Regulations pertaining to Licences for Radio Amateurs that may be in force at any time.

The licence is valid
until 1. jan 1984

Reykjavík, 22. júní 1983
The Post and
Telegraph Administration

The undersigned has on behalf of the Radio Inspectorate of the Post and Telegraph Administration, examined the equipment Station PA2OHH/TF wich is in conformity with the said Licence.

The licence for Island in 1983..

Paperwork and customs
At that time, you needed a license for each country. I did that always for the countries where I was QRV: Denmark, Norway, Sweden and Island. But they never were interested in the QRP transceivers and licences. There was another object, everyone was looking at it very suspiciously: the fishing rod used for the antenna! Fishing is illegal everywhere and if you should do that, they will kill you! Very often I had to explain that I did use that fishing rod only for the antenna and not for fishing!

Portable with ice cold red toes in the ice cold forest!

QRP practice
And then you are standing barefoot in the pricking thistles. The antenna connected, the sked was successfull and then you want to work a couple of other stations. Calling CQ but no answer. Again with your bare feet in the prickling thistles to change the antenna direction, calling CQ and again no answer. So the antenna direction was not the problem. Normally you do give up and you are convinced that QRP does not work. But I did read some extra radio books. Indeed, calling CQ with a QRP signal does only work around the QRP frequencies, mention also that you are QRP. But with QRP, you have to do it differently. Answer a CQ calling station instead of calling CQ yourself. That does work already much better, except when also stronger stations are answering. Then you have to loose of course. Whan also works is calling a station after the end or a QSO. Mostly they will come back for you.
The next day on bare feet in the snow on the mountain I could try out the new practice. And now I could make QSO's. Suddenly QRP was nice and I continued till my ice cold toes were half frozen in that cold snow. And the batteries that were kept warm under the thick coat were empty.


Cold winter weather, warm summer weather and portable at such beautiful places in nature! What do you want more!


How much fun can you have with such a cheap and simple portable station on bare feet!
Not only to feel branches and stones, but also to feel the cold was something I really had to get used to.

Controlling the Barefooter
When you switch from transmit to receive, you have to retune the VXO a little, otherwise your receiver is zero beat with the other station. We want to keep this offset tuning as small as possible. Therefore, the other station will be heard with a low frequency audio tone. Just before the end of the transmission of the other station, we have to tune zero beat to be able to transmit on the exact frequency. If you should forget that, you will be heard most of the time when the offset is small. But there is another important reason: 400 Hz is not the most sensitive frequency of the ear but indeed the most selective frequency!

Antennas
The antenna was a dipole between the trees when camping in the woods. Stones were used to throw the ropes and antenna wires over the branches. Or the same dipole was used as inverted V with the center at 4 meters using a fishing rod as a support. Also a quarter wave vertical, using the same fishing rod with 6 wires of 2meters radial wires as groundplane was used.
All antenna's worked well, I never had an SWR meter with me. The vertical with the radials was made from loudspeaker wire and a PL259 plug, sold in a local shop in Sweden. The wire length was calculated and I never verified the SWR...

PORTABLE ON BARE FEET!

Portable on bare feet in the woods!
Of course it was silly to walk barefoot in the woods. A normal person does not do that! Barefoot on branches, stones and even thistles and with cold red toes in the woods, that has to be really horrible! We had expected that it would be a real torture for my bare feet, but that was not the case! I did feel the branches and stones quite well but they were not really painful for my bare feet. Thistles do prickle a little! Walking barefoot in the woods, you do have to learn it. *First put down you toes and then your heels, then walking barefoot goes already much better.* That is the natural way of walking, but is not possible with shoes on! I had to get used to it but after a while, it was not difficult at all and even nice to walk barefoot in the nature. It was even so nice, that I would do that more often! Walking barefoot in the woods, unbelievable but it was possible and even very nice not only to see, but also to feel where you are walking! Although... sometimes a thorn had to be removed.


Back to basic! A portable station on bare feet, that was the new challenge.
Barefoot in nature where we normally go with thick hiking shoes!

Barefoot in the snow!
Barefoot in the snow... Even that is possible if it is not colder than -3C. And there was still much snow in the mountains. Of course it was really crazy to go barefoot over there in this cold, wild winter landscape with stones, snow and ice! The first time, the cold was so unbearable, that I thought that I would die. But there was no spot without snow, so I had to go on.
And suddenly, after a few minutes, that unbearable feeling disappeared. Then it felt as if I could walk barefoot to the North Pole. After a few times, getting used to the cold was much easier and then I did not understand anymore why it was so unbearable cold the first times. Unbelievable, but after some practice, I could walk barefoot in the snow and on ice during one hour without any problems! Sometimes I was even completely forgotten that I did go barefoot in the snow!


Barefoot in the snow for a hike and to work portable!

Of course I had cold bare feet and ice cold red toes, that is unavoidable and belongs to it. It was nice to walk barefoot in the snow and on the ice of a still frozen mountain lake. It was also a challenge because we, modern people, do not do that anymore and find it awful. Often I also did go for a walk on bare feet in the snow and on ice during the winter. But then it should not be colder than -3 to -4C! Fresh snow during the winter is very soft and not so cold and hard as the melting snow in Norway and Sweden during my holidays. And ice is not very slippery!

BACK TO INDEX PA2OHH

RCA BTE-10B Direct FM Modulator Exciter and BTX-1A SCA Multiplex Generator

This article was published by RCA in Broadcast News, Vol. No. 102, October, 1958.

NEW FM TRANSMITTER AND MULTIPLEX EQUIPMENT

5-KW FM Transmitter, Type BTF-5B, Designed for Multiplex and Conventional FM Operation; Exciter and Subcarrier Generator Designed for Converting Existing Transmitters to Multiplex Operation

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FIG. 1. Front view of the BTF-5B FM Transmitter. Cabinet on the left houses the PA stage. Cabinet on the right houses the IPA, the BTE-10B Exciter, and enough space is provided for mounting the BTX-1A Subcarrier Generator.

Over 500 FM stations are now on the air and more are applying. Background music service has become a very profitable programming concept for many stations, and now stereophonic programming may enter the picture. Multiplexing offers a station added sources of revenue by enabling it to offer several different types of programs.

In order to fill the broadcasters need for economical, easy to operate multiplex equipment, RCA has developed a new FM equipment line. New installations can be

A 5-KW FM Transmitter

To assure outstanding multiplex performance RCA offers the Type BTF-5B FM Transmitter. This 5-kw unit has been designed for multiplexing, and it will also offer outstanding conventional FM performance. The BTE-10B Exciter is used to drive the IPA stage, where a single 7034 tube produces 250 watts (see Fig. 2). The PA stage is composed of a single 4CX5000A tube which produces the 5000-watt output. Only two tubes are used beyond the exciter to produce the 5000-watt ing the unit. The BTF-5B cabinet has been designed along the same lines as the BTA-500R/1R AM Transmitters. Colored doors are available on the BTF-5B. The exciter cabinet is attached to the PA cubicle, and another cabinet can be added to house input and monitoring equipment.

Multiplex Transmission

Multiplexing is the simultaneous transmission of two or more separate program channels on the same rf carrier. One program will frequency modulate the rf

equipped from microphone to antenna, and existing installations can be converted to multiplex operation by adding individual units. For new installations, the Type BTF-5B FM Transmitter is a complete unit which, with the simple addition of a Type BTX-1A Subcarrier Generator, becomes a multiplex transmitter. For existing installations, the BTE-10B Multiplex Exciter and the BTX-1A Subcarrier Generator are ideal for converting most existing transmitters for multiplex operation.

FM signal.

Dry disc rectifiers are used in the variable screen grid power supply for both IPA and PA. The high-voltage supply is made up of six 8008 mercury vapor tubes, which also feeds both stages. The exciter and subcarrier generators both have self-contained power supplies.

The subcarrier generator is not supplied with the transmitter; however, space is provided in the exciter cabinet for mount-

carrier in the conventional manner; this constitutes the main program channel which broadcasts programs intended for the general public. The main channel can be received on conventional FM broadcast receivers.

An additional program channel can also be modulated on the same rf carrier; however, this second channel is selected so that it does not interfere with the main program channel. To prevent interference with

the main channel, it is necessary to transfer the subchannel program into the supersonic frequency range, and this is accomplished by frequency modulating the subchannel program on to a 30-67 kc subcarrier. This frequency modulated supersonic carrier is then used to modulate the rf carrier; thus, the main carrier contains two separate programs. As many as two subcarriers can be inserted on a single main rf carrier, and the new RCA multiplex equipment is capable of transmitting a main and two subchannels.

Multiplex Standards

No standard subcarrier frequencies have been set at this time, however, a number of frequencies are being used. The new RCA Type BTE-10B Multiplex Exciter and the Type BTX-1A Subcarrier Generator will operate on the popular subcarrier frequencies now in use (as well as others). Frequencies now in common use are 32.5, 42, 58 and 67 kc. One hundred percent modulation of the subcarrier has been set at a frequency deviation of ±7.5 kc. It is possible to transmit several subchannels along with the main channel, if the sum of the frequency deviations for sub and main channels does not exceed the maximum FCC limit of ±75 kc.

Subsidiary Communication Authorization is the FCC terminology for multiplex operation, and these SCA rules limit the instantaneous frequency of the subcarrier (including frequency deviations of the subcarrier due to modulation) to a range from 20 to 75 kc. Furthermore, the modulation of the (main) rf carrier by the subcarrier, or the subcarriers shall not be more than 30 percent of the maximum deviation allowed on the rf carrier, which is ±75 kc. In other words, the maximum subcarrier swing of the main rf carrier cannot exceed ±22.5 kc. These rules are not considered final, and may be changed in the future.[1]

How Multiplexing Is Used

The program modulated onto the subcarrier will often consist of background music; however, speech or other intelligence may be used subject to FCC approval. Tests are being conducted that may provide the answer to the feasibility of FM stereophonic broadcasting. Care has been taken in the design of the RCA equipment to make this application possible.

System Performance

FM broadcast multiplexing is a completely new technique to many FM broadcasters. While no new phenomena are encountered, multiplexing has a definite

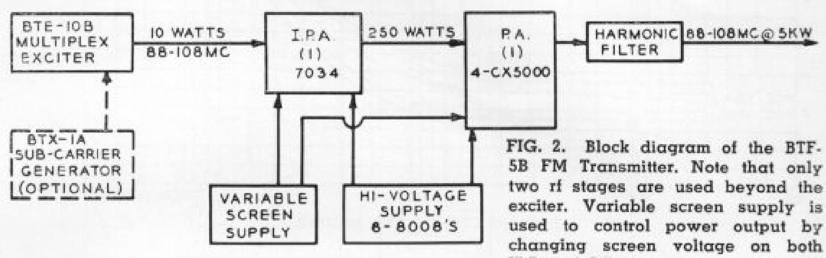
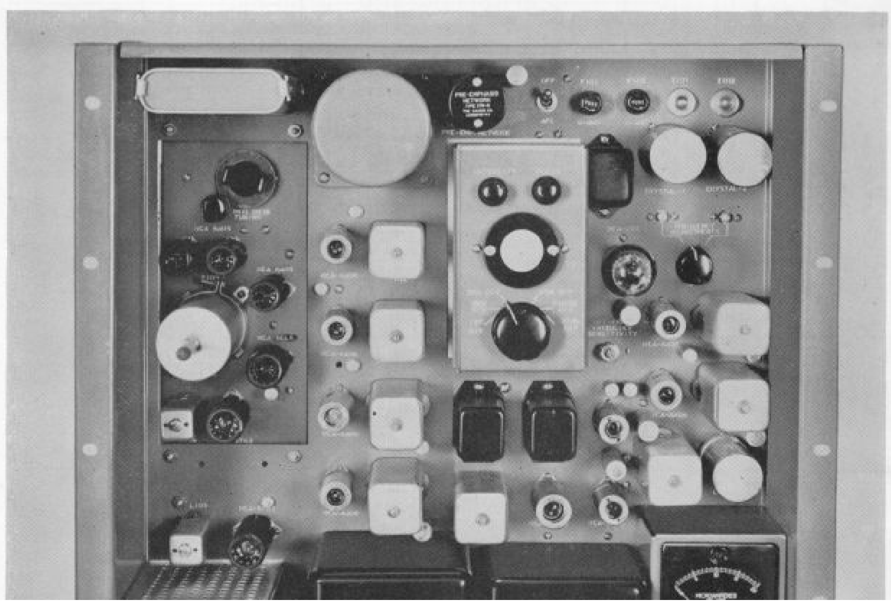


FIG. 2. Block diagram of the BTF-5B FM Transmitter. Note that only two rf stages are used beyond the exciter. Variable screen supply is used to control power output by changing screen voltage on both IPA and PA stages.

FIG. 3. Here the vertical chassis of the BTE-10B Exciter is shown. The built-in scope permits constant observation of the AFC circuits. The meter, in the lower right side, is used to check all important circuit constants.



Receiving Equipment

The FM receivers used by the general public will, as mentioned before, not be noticeably affected by the presence of the supersonic subcarriers or their modulation. To receive the subchannel, or the subchannels, special receiving equipment that incorporates provisions for detecting the subcarrier will have to be used. RCA carries a line of these special multiplex receivers and thus provides a complete system.

[1] See Federal Communications Commission Notice of Inquiry, Docket No. 12517, Released July 8, 1958.

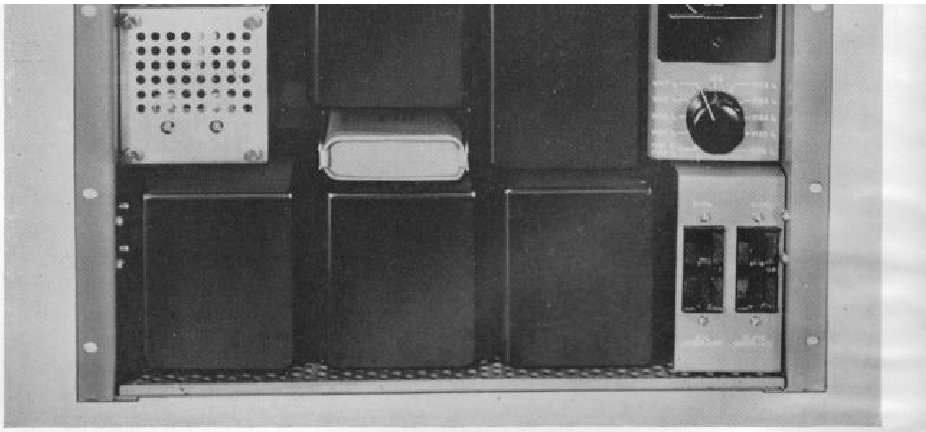


FIG. 4. Actual frequency response curve of a typical BTE-10B Exciter is shown here in comparison with the RCA specification limits and with the maximum FCC limits.

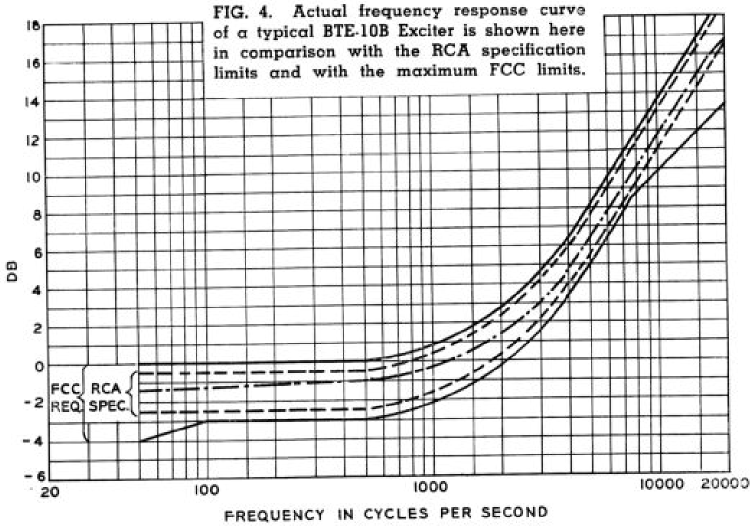
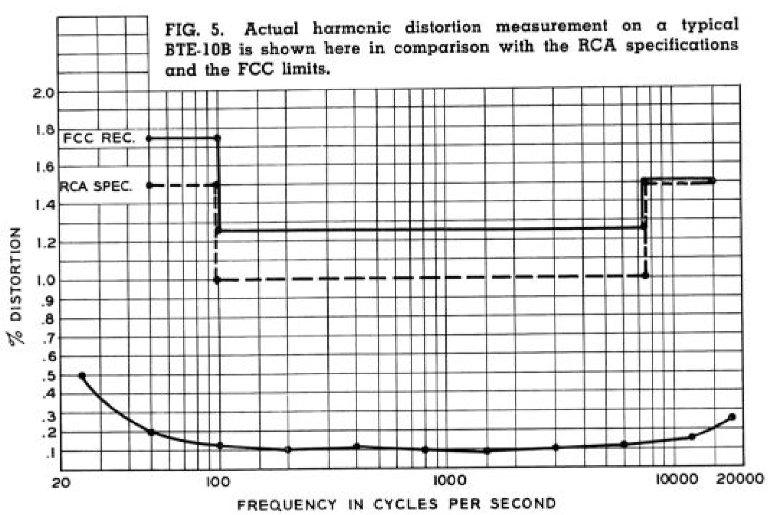


FIG. 5. Actual harmonic distortion measurement on a typical BTE-10B is shown here in comparison with the RCA specifications and the FCC limits.



effect on the over-all system performance that requires a little more attention.

In conventional FM service (meaning the transmission of only one program on the rf carrier and no subchannels) there are mainly three transmitter design considerations which affect performance: (1) frequency response, (2) harmonic distortion and (3) the ratio of the wanted signal to the unwanted noise (signal-to-noise ratio, or S/N). In addition to these considerations, crosstalk between channels must be added when considering a multiplex system.

Frequency Response

Typical performance data for frequency response is given in Fig. 4. The curve shown should be compared with RCA specifications and also with FCC requirements both of which are included in Fig. 4. It should be noted that performance is measured from 50 to 18,000 cps. Frequency response of the exciter is mainly determined by the quality of the audio frequency components used in the modulator section of the exciter. The rf circuits following the reactance tube modulator and the master oscillator have no appreciable effect on frequency response; therefore, it cannot be upset by improper tuning of the rf section. This would not have been so if very narrow bandwidth rf coils had been used. Furthermore, the exciter needs only three tuned stages to get up to the final output frequency in the FM broadcast band.

Harmonic Distortion Measurements

Harmonic distortion is a more intricate problem. Nonlinearities of the phase vs frequency curve of the tuned circuits in

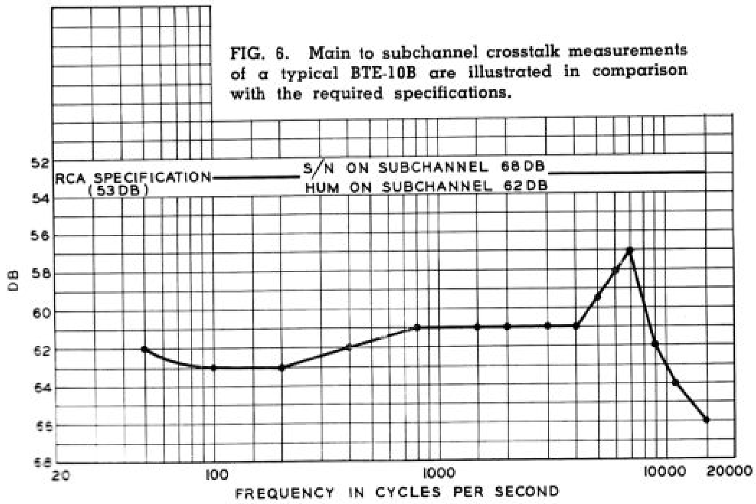


FIG. 6. Main to subchannel crosstalk measurements of a typical BTE-10B are illustrated in comparison with the required specifications.

connection with nonlinearities of the voltage vs current curves of the tubes creates harmonic distortion. The degree of distortion depends on the degree of nonlinearities. The distortion can differ greatly at different audio frequencies; and it is, of course, dependent on the percentage of modulation. To a lesser degree distortion is also created by improper amplitude response of the tuned circuits, but under practical conditions this may be disregarded. Many times in addition to harmonic distortion, figures are given for intermodulation distortion. While both types are not directly interrelated they can be attributed to the same shortcoming of the components used and one is representative of the other, meaning low harmonic distortion will indicate low intermodulation distortion and vice versa. It should be

remembered that in order to get the ultimate of low distortion output from *any* FM transmitter (or receiver) all tuned stages should be tuned for minimum distortion employing a distortion analyzer as indicating device.

Figure 5 gives typical performance data of a BTE-10B Exciter for harmonic distortion together with the limits called for in the specifications. It must be noted that the distortion is so low that the limit of accuracy of the measuring device is in the same order as the exciter distortion.

S/N Ratio

The type of modulator used will determine to a large extent the signal-to-noise ratio, and S/N is practically unaffected by the rf circuits following the master oscillator. For practical reasons, noise and ac hum should be read separately using an appropriate filter to separate both components. Many times —50 db hum level is less objectionable than —60 db noise level, yet reading both with a peak VTVM would indicate —48 db signal-to-noise ratio.

FCC requirements on the signal-to-noise ratio are —60 db, and RCA specifications call for —65 db while figures for the new exciter approach —78 db noise and —75 db hum. In addition to the FM noise level an AM noise level is specified. These are not related, the latter just indicates the "cleanness" of the carrier with respect to any unwanted amplitude modulation. RCA specifications call for —50 db and figures for the exciter can be as low as —70 db.

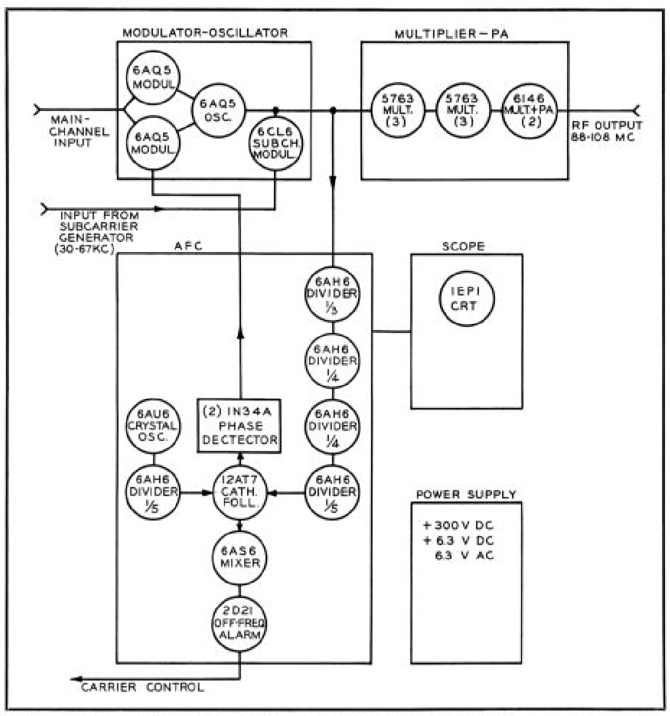
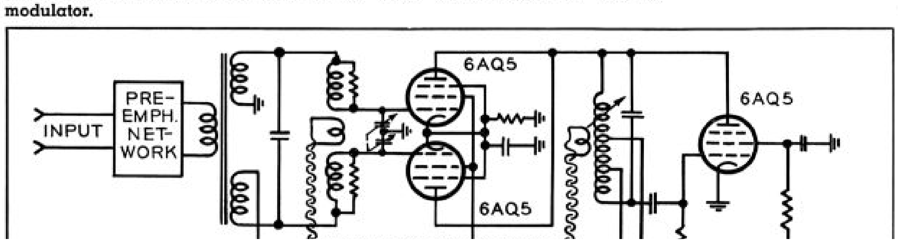


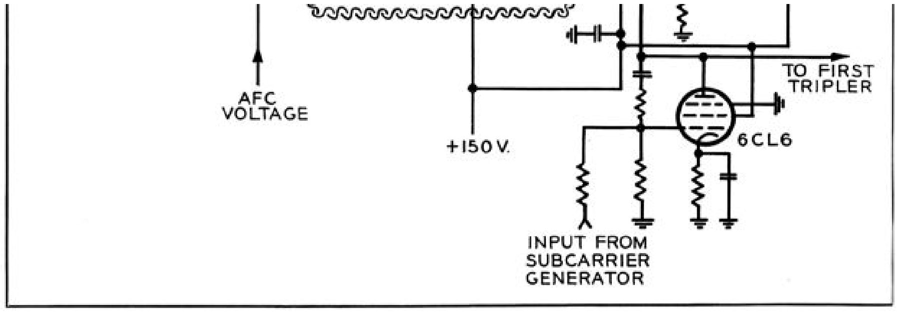
FIG. 7. Simplified block diagram of a BTE-10B Exciter. The modulator-oscillator is shown with provisions for inserting one subcarrier.

FIG. 8. Simplified schematic of the BTE-10B modulator-oscillator. The 6AQ5 balanced modulators act as variable reactances on the 6AQ5 oscillator. Subcarrier modulator (6CL6) acts in the same manner as main channel modulator.



Crosstalk and Multiplexing

A multiplex system will require some additional information to describe the performance of a transmitter. First, all of the above data should be obtained for the one or more subchannels. In the RCA system, subchannel performance in areas such as frequency response, distortion and signal-to-noise ratio are maintained as nearly comparable to the performance of the main channel exciter as possible.



Reduced Crosstalk

Finally, another consideration has to be added—intermodulation between the different channels. This is by far the most difficult problem. There are three types of intermodulation, also referred to as crosstalk: from main-to-subchannel, from sub-to-main channel, and from one subchannel to another subchannel. Intermodulation stems from the same transmitter shortcomings that cause harmonic distortion. It may easily develop because of improper tuning of the rf multipliers. The increased harmonic distortion might very well go unnoticed by the average listener; however, a 15 db increase of crosstalk from the same cause can be much more easily detected. In multiplex operation the transmitter has to be of excellent quality and it must be kept in better condition to work satisfactorily, and this requires better measuring equipment and test techniques.

The degree of perfection required depends on the type of service to be used. In a background-music installation crosstalk from the main channel into the subchannel is highly undesirable. While in a stereophonic application this, because of the similar nature of the program in the two channels, is not as important. On the other hand background music requires only frequencies up to 6 kc, while stereophonic applications will probably require better frequency response. Typical performance

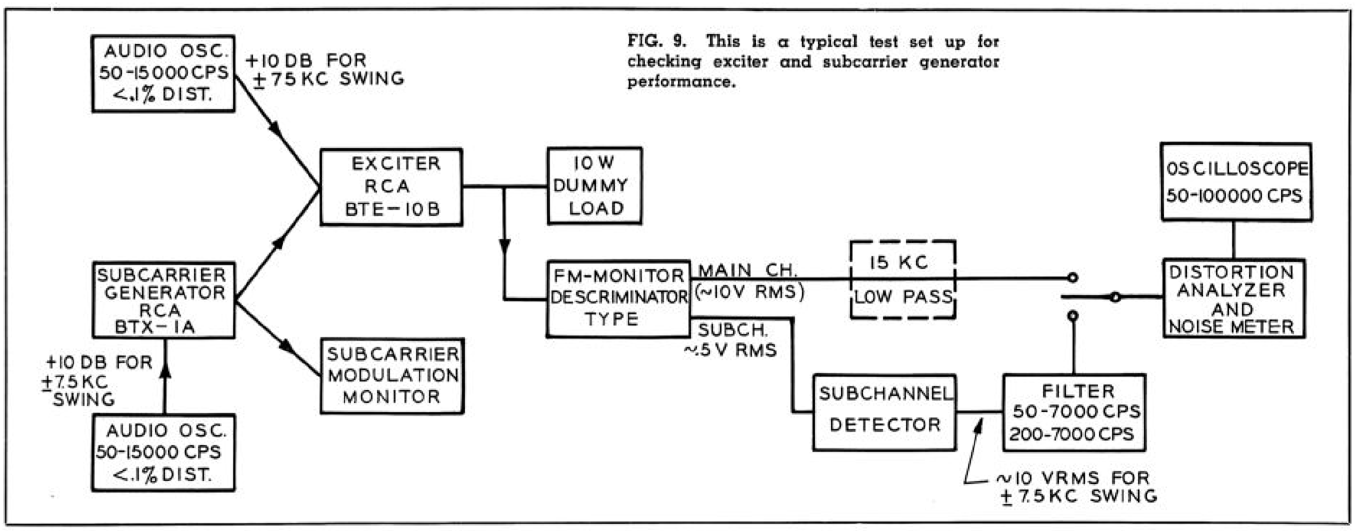


FIG. 9. This is a typical test set up for checking exciter and subcarrier generator performance.

data of main-to-subchannel intermodulation is given in Fig. 6. These figures are not exciter data but system data, covering exciter, monitoring, and detection devices. There are indications that the exciter alone is a few db better than indicated in Fig. 6.

Crosstalk from the subchannel into the main channel shows the same slight increase toward the higher audio modulating frequencies and is about 10 db better than the main-to-subchannel crosstalk. Sub-to-main channel crosstalk is almost independent of rf multiplier tuning.

Exciter Circuit Advantages

The subcarrier reactance tube is coupled only to a small part of the oscillator coil, since the deviation of the rf carrier by the subcarrier is rather small.

Both modulating circuits are very effectively decoupled thus minimizing the possibility of crosstalk between the two channels.

Automatic Frequency Control

The AFC circuit with associate off-frequency detector has recently been described.[2] The circuit used in this exciter is essentially the same except for a simpler

rated into the exciter. A switch permits instantaneous checking and adjustment of all five dividers and a check of the control action of the phase detector. All waveform displays are in form of Lissajous figures with the advantage that lock-in of the dividers can very easily be observed. Furthermore, this type of display needs no synchronization or any other adjustment. All checks can be made during operation without upsetting the AFC circuit in any way.

A built-in meter can be switched to read the following voltages, currents and power: modulator cathode current, second

The Type BTE-10B Exciter in conjunction with the 250-watt IPA is used to drive a single 4CX5000 tube in the BTF-5B FM Transmitter for ordinary FM service or multiplex operation.

A block diagram of the exciter is given in Fig. 7. A simplified schematic of the modulator-master oscillator portion is shown in Fig. 8. A Hartley-type oscillator is used in conjunction with two reactance tubes for the main channel and a third reactance tube for the modulation of the subcarrier on the (main) rf carrier. This method has several marked advantages.

The push-pull modulator is highly linear resulting in very low harmonic distortion. The coupling circuit is such that each tube is almost a pure reactance, one inductive, the other capacitive. In this way, loading of the oscillator is greatly reduced giving better AFC action. Furthermore, the push-pull modulator will balance out temperature and supply-voltage changes automatically. The low AFC control voltages required assure proper operation even if the uncontrolled oscillator is off-frequency.

(due to simpler circuit requirements) divider arrangement and the use of miniature tubes throughout.

The circuit used has a long record of very reliable operation. Since a phase detector is used to develop a control voltage the system is, strictly speaking, an automatic phase control system that tries to establish and maintain a phase lock between the reference and the derived signal. Therefore the stability achieved is the same as the stability of the reference source.

The precise control achieved this way is normally traded against a very limited range of control. This limitation is overcome by the use of the off-frequency circuit which extends the pull-in range of the control circuit to ±300 kc (at the final frequency) and at the same time provides a safeguard against uncontrolled and possible off-frequency operation.

In order to simplify adjustment and maintenance of the AFC dividers a monitor oscilloscope is permanently incorpo-

[2] "A New Visual and Aural TV Exciter," *Broadcast News,* Vol. No. 99, February, 1958.

and third multiplier grids, PA cathode and plate current, AFC control voltage and plate voltage. The rf multiplier and PA use single tuned circuits, thus making adjustment simple. The final amplifier of the exciter is a doubler.

Exciter Power Supply

Semiconductor rectifiers are employed throughout the exciter power supply. One bridge-type germanium rectifier is used for the high-voltage supply and a full-wave silicon rectifier for the modulator oscillator filament. The exciter can be operated from any single-phase source having a voltage of 197 to 251 volts, or 106 to 128 volts ac at 50/60 cps.

One circuit breaker is provided in the high-voltage supply and one in the ac input. They both serve at the same time as master and stand-by switches. There is a separate connection for the 117-volt crystal oven heater supply. The oven heater should be energized continuously. Each circuit (one operational and one spare crystal) is protected by ¼-amp fuses.

Monitoring Multiplex Signals

The method of measuring several multiplex parameters will now be discussed. The measuring arrangement is shown in Fig. 9. Care should be taken to select the test equipment to suit this application. Both audio generators should be of low initial distortion, preferably 0.1 percent or less.

To monitor the subchannel a multiplex monitor can be used with the subchannel signal fed directly in the subcarrier adapter section of the monitor. The FM monitor and subcarrier detector will be contained in the FM multiplex monitor. However, should this unit not be on hand a standard FM monitor of the discriminator type may be used together with an adapter from the multiplex receiver.

The filter shown in Fig. 9 is not absolutely required, but is very useful in eliminating unwanted components, such as hum. As waveform monitor, any oscilloscope good to 100 kc may be used. Frequency response and distortion as well as signal-to-noise on the main channel can be measured the usual way. Similarly, these parameters can be measured for the subchannel.

To measure signal-to-noise ratio on the main channel with subcarrier modulation

FIG. 10. All operating adjustments on the BTX-1A Subcarrier Generator are accessible from the front of the unit as shown here. Again the convenient built-in oscilloscope can be used to observe operation of AFC circuits. The author is shown checking divider circuits.

present, the filter must be used to eliminate the subcarrier. An electronic filter is very suitable for this purpose.

Crosstalk Measurements

Main-to-subchannel crosstalk is where the measurement of special multiplex parameters should begin. To set the reference the subchannel should be modulated 100 percent (±7.5 kc deviation) with a 400-cps tone. Set the distortion analyzer for noise measurement, and adjust the meter deflection to 0 db. The filter should be set to pass a band from 50 to 15,000 cps (see Fig. 9).

Now remove the subcarrier modulation and apply modulation to the main channel using a number of frequencies from 50 to 15,000 cps, adjusting each frequency to 85 percent modulation if one subchannel is used. (If two subchannels are used, the main channel should be modulated 70 percent instead.) Read the crosstalk for all frequencies on the distortion analyzer.

Next, modulate again 400 cps at 85 percent to the main channel, and carefully adjust all multiplier stages of the BTE-10B exciter to give a minimum crosstalk reading. Make sure not to detune the tuned circuits too much. Also *touch up* the monitor tuning (rf and i-f coils, and dis-

FIG. 11. When used with two subcarrier generators, the BTF-5B is housed in three cabinets as shown above. (Normally the BTF-5B is housed in two cabinets, see Fig. 1.) All cabinets for this transmitter are available in a choice of red, blue, green, or umber-gray doors.

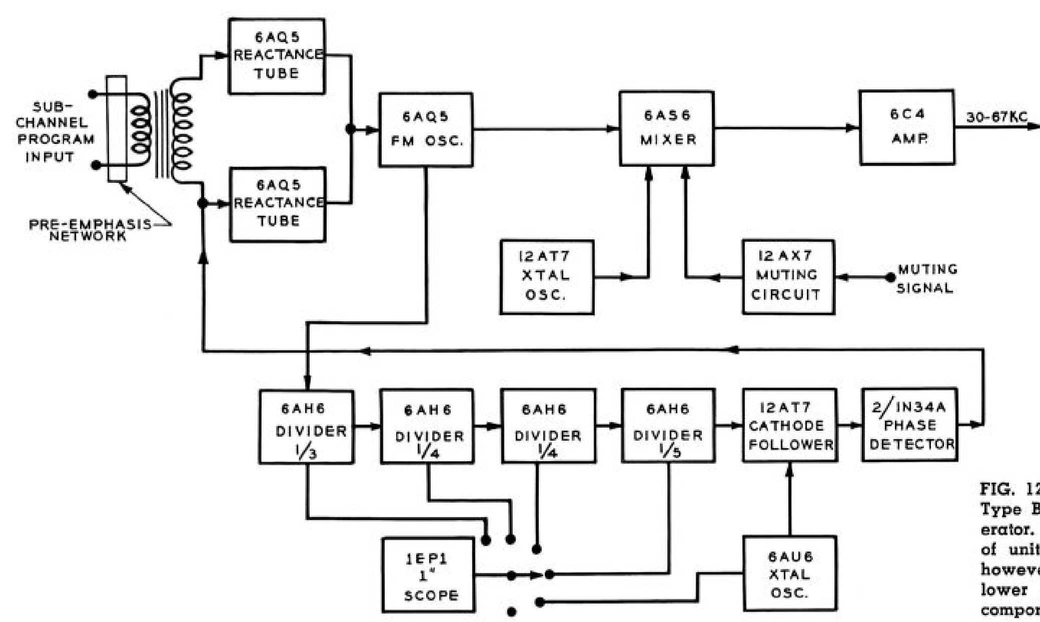


FIG. 12. Block diagram of the Type BTX-1A Subcarrier Generator. General arrangement of unit is similar to exciter; however, it operates at a lower frequency, and fewer components are required.

criminator), and make sure that the monitor and separate subcarrier adapter, if used, are fed with the right amplitudes and not overdriven.

If necessary, repeat the steps indicated above, however, slight adjustment of the first tripler coil should correct any possible excessive crosstalk on 6 kc. Make sure by observing the waveform oscilloscope that the meter indication on the distortion analyzer represents the components required. Certain beat frequencies generated in the monitor may give a false impression. It should be noted that the above adjustment is greatly simplified because only three tuned circuits may contribute to crosstalk. In some instances it may be advantageous to slightly shift the modulator grid tuning capacitor to give 2 to 3 db better crosstalk reduction. The subcarrier modulator itself requires no tuning.

In a similar way sub-to-main channel crosstalk will be measured. This time the 0 db reference is 100 percent modulation (±75 kc deviation) by a 400-cps tone on the main channel. This modulation then is removed and tones from 50 to 6000 cps applied to the subcarrier generator, giving 100 percent (±7.5 kc) modulation on the subchannel. Slight crosstalk may result from improper balancing of the main channel modulator tubes. Therefore, the modulator grid tuning, after initial setting for maximum swing should ultimately be tuned for minimum sub-to-main channel crosstalk. This setting requires only a very slight change. The exciter multiplier tuning has practically no effect on sub-to-main channel crosstalk.

From the above, the last measurement has become quite obvious. To measure possible intersubcarrier crosstalk one proceeds in the same way, setting a reference level for the channel in which crosstalk is being measured by first modulating it with a 400-cps tone at 100 percent modulation (±7.5 kc).

The Subcarrier Generator

Although the Type BTX-1A Subcarrier Generator has already been discussed in conjunction with the exciter, it deserves some separate description. Basically, the exciter and subcarrier generator are of similar design (compare Fig. 7 with Fig. 12); however, due to the lower frequencies encountered in the subcarrier generator fewer components are required.

Operation is similar to the exciter. Exact frequency of the subcarrier is determined by beating the FM exciter master oscillator frequency with that of a crystal oscillator, the resultant signal will be at the subcarrier frequency selected in the 30 to 67 kc range (see Fig. 12).

Background-music operations often use supersonic control tones. Interference between main and subchannel occurs when the control tones are transmitted. To prevent this interference, a muting circuit is used in the subcarrier generator which will cut off the subcarrier when control tones are being transmitted.

The Type BTX-1A Subcarrier Generator, when combined with the BTE-10B Multiplex Exciter, can be used to convert existing transmitters to multiplex operation; however, the type of transmitter used will have a great effect on the final signal. All exciter and subcarrier generator specifications will only hold true to the output of the exciter, except when used to drive the RCA Type BTF-5B FM Transmitter, then the over-all transmitter performance will meet specifications.

Conventional FM Operation

Since this new transmitter and exciter have been designed to meet the more stringent requirements of multiplex operation, they will obviously offer superior performance for single channel operation. Stations now in operation can use this equipment for the present, and later if multiplex operation becomes desirable all they need to do is add the subcarrier generator.

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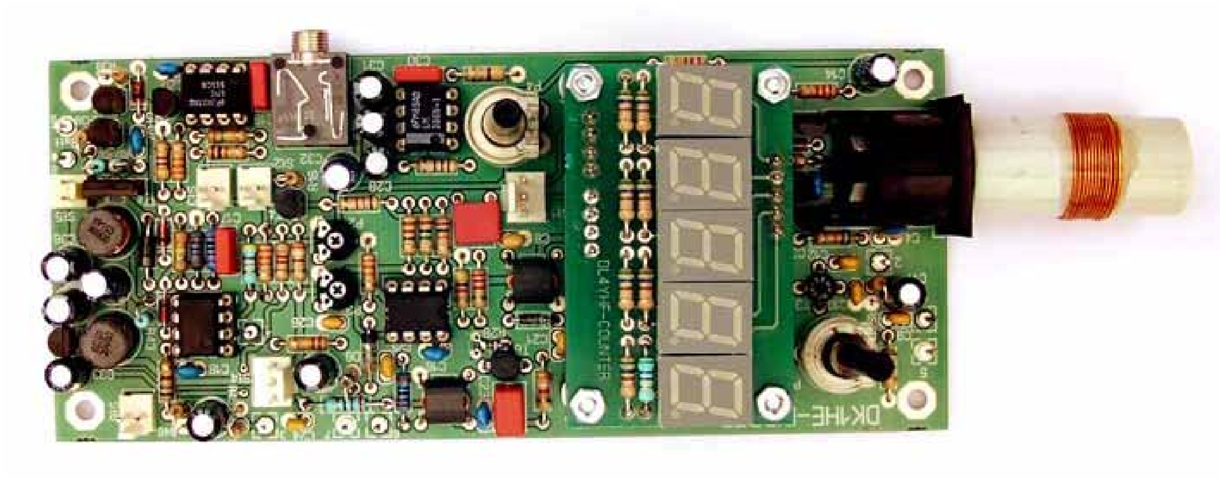
John's Home Page

DipIt, the revolutionary Dipmeter of the German QRP Club

DL-QRP-AG.



Idea and Design by Peter Solf, DK1HE

Project Coordination by Peter, DL2FI

Kit Realisation by Nikolai, DL7NIK

Thanks to the help of Pete, WK8S the english manual is now available. Download here

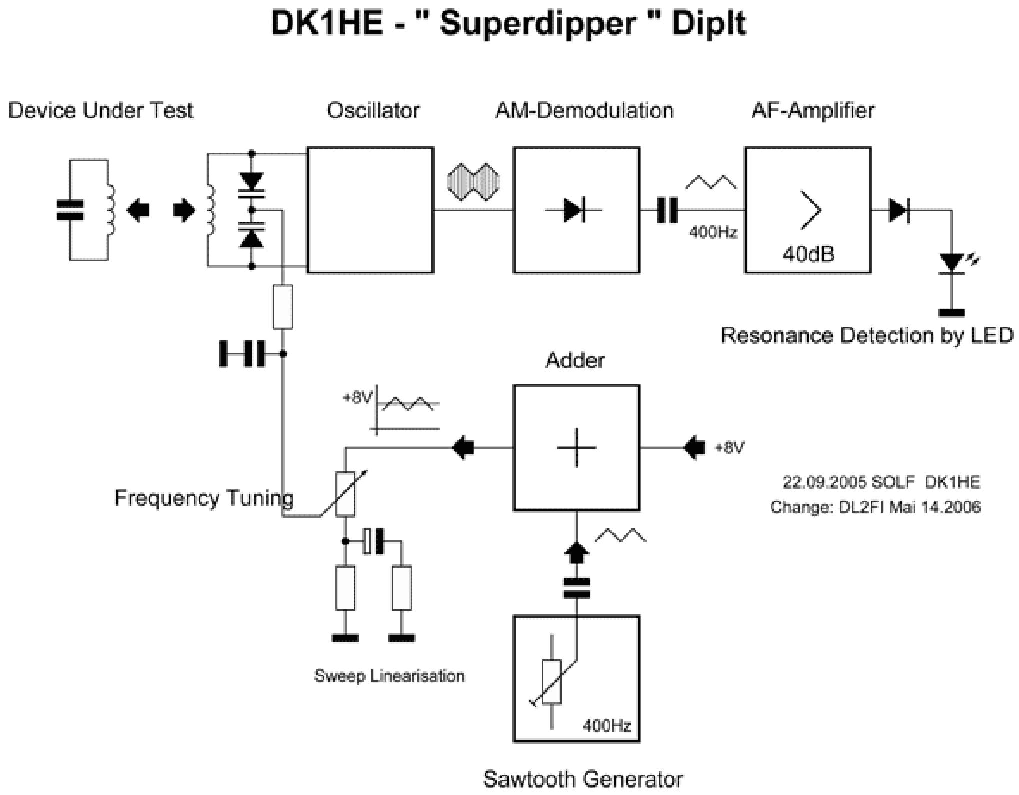
The DL-QRP-AG DipIt works in a complete other way:

The heart of the circuit is the varicap tuned variable oscillator with a tuning range of about one octave. The Tuning-Voltage is overlaid by a small sawtooth voltage which causes a symmetrical frequency modulation (sweeping) of the VFO. The chosen frequency sweep is approximately +/- 0.2% of the current oscillator frequency. The sweep frequency is approximately 400 Hz. If DipIt is coupled to a device, DipIt´s frequency will sweep over the resonance curve of the Device Under Test (DUT). This is the same what a user normally does with a conventional Dipmeter by sweeping the Main Tune Knob for a little amount to find the Dip.

Sweeping the VFO by 400 Hz over the resonant curve of the DUT results in an Amplitude Modulation (AM) of the VFO. Why? The DUT will absorb energy of the VFO if it is on the same frequency as the Dipmeter. Because the Dipmeters frequency is swept by 400 Hz, the Amplitude of the VFO will go up and down by 400 Hz - this is what we all know as Amplitude-Modulation (AM). The degree of modulation is greater the more exact DUT and Dipmeter are tuned to the same frequency and the harder the coupling between both is. A following AM demodulation stage separates the 400 Hz AC tone. The display part of DipIt is a simple 40dB AF Amplifier, a rectifier and a superbright LED. Using this method, the only criteria of detecting resonant devices is the AM-Modulation so the different Amplitude height of the VFO depending on its frequency is no longer a problem. That fact, that an AM signal can

be amplified very easy increases the sensitivity of the dipper dramatically.

- Coupling between DipIt and DUT can be much looser then with any conventional dipmeter, the dip is absolutely clearly.
- DipIt works as a Direct Conversion Mode Frequency Meter. To make DipIt more flexible, we added a Direct Conversion Frequency Meter.
- With a simple probe made from a piece of coax cable and a capacitor we can connect DipIt via its built in Cinch connector to any RF signal source.
- With its Attenuator, Mixer and separate AF Amplifier DipIt becomes a complete Direct Conversion Receiver working over the same range as it does in Dipper mode. This makes DipIt ideal to measure the output of TX-Mixers, output of bandpassfilters in a TX chain and others. Both DipIt modes together plus the standard Absorption Mode make DipIt a tiny and cheap replacement for a (much more comfortable) Spectrum Analyser.



The Circuit:

The VFO is a Hartley Oscillator with a JFET T1 (BF2456B). It consists of the plug in coil L1 and the two anti serial Diodes D1/D2. A 10 turn Pot enables a smooth tuning range of 1 octave. By using 5 different plug in coils, DipIt has a complete range from about 1 to 42 MHz. Because in our opinion its not a good idea to use the same oscillator design for a range from 1 MHZ up to the VHF area, we decided to develop separate plug in Oscillators later for UHF and VHF use. Diode D3 automatically generates the negative Gate Voltage and acts as an AM demodulator the same time. The R/C circuit R2/C2 is a lowpass Filter with an upper border of about 4 kHz. At C2 the demodulated 400 Hz signal is taken and connected via S1 to the following Amplifier.

The Sweep Generator

IC3 acts as an R/C oscillator and produces a symmetrically sawtooth of about 400Hz. The Voltage divider R19/R20 reduce the Amplitude of the sawtooth to the value we need. IC2a is working as an adder that adds the sawtooth to the DC-Voltage from R18. At the output of IC2a we find 8V DC plus symmetrically overlaid sawtooth of some 60-80mV. R45 defines the Tuning range. The R/C combination plus Pot P5 form a Voltage divider for the sawtooth part and they linearize the typically S-shaped curve of D1-D2. So the sweep range is nearly constant over the whole VFO range.

Display Amplifier

The 400Hz AC Signal is amplified in IC1a, amplification ratio is 40dB. C15 decouples the AC signal from it's DC part. By P2 the quiescent level can be adjusted so that the LED outside of a resonant situation is just glowing a little bit. At this point the LED additional acts as a rectifier. If there is an AC signal, the positive half-waves let a current flow through the LED. The brightness is direct proportional to the amplitude of the signal. Transistor T4 serves as current source for the LED, R15 limits the If a user likes to use a needle instrument (Voltmeter) this one can be added parallel to the LED.

Buffer, Power Amplifier and ALC

By C3 the VFO Signal is coupled to a FET Buffer T2. The frequency counter is low impedance coupled at the source of the buffer by BU3. The buffered VFO Signal also is used as Local Oscillator Signal (LO) for the integrated Direct Conversion Frequency Meter. By transformer TR1 the buffered signal is coupled to the power amplifier T6. Amplification is adjusted by R28 to 20dB. Transformer TR2 transforms the dynamic collector resistance of T6 to the system impedance of 50 Ohm. This amplified RF Signal can be taken from DipIt at the Signal Generator Output Jack BU 6. To get a constant level of +7dBm independent from the actual frequency, the circuit around T6 is designed as VCA, Voltage controlled Amplifier. The actual output is decoupled by R29 and rectified by D6/D7. The resulting Voltage is feed as an “IS” Voltage to the inverting input of IC1b. The Output is controlled by the “To BE” Voltage at the non inverting input of IC1b. PIN Diode D5 together with R23 act as a RF Voltage divider. So if the Actual rectified RF Voltage is lower at PIN 6 of IC1b is lower then the control Voltage at PIN 5 IC1b, the output of IC1B gets positive causing a higher current in D5 which makes it's dynamic resistance lower. The RF Input at the Base of T6 increases until the rectified RF output Voltage has the same value as the control voltage.

Direct conversion Frequency Meter

We integrated an instrument into DipIt which was an absolutely “MUST HAVE” for long times but has been nearly forgotten the last years: the Direct Conversion Frequency Meter or Zero beat Frequency Meter because it extreme useful to have it when building Amateur Radio Kits without access to other frequency selective metering devices like Spectrum Analysers. We use a MOS Tetrode as Direct Conversion Mixer. Gate 1 is coupled to the input Jack Bu5 by a variable attenuator P1, Gate 2 gets the LO signal from the Buffer Circuit. The output of the mixer T3 is coupled to the Display by switch S1 and amplified by IC4 to control it by headphones. If DUT frequency and VFO frequency are nearly the same, the conversion tone will be heard in the headphones. If the VFO is tuned to “ZEROBEAT” , that is the frequency where the tone just disappears, the frequency-counter will show the exact frequency of the measured DUT signal. The Sweeper must be shut off during this measurement!

Absorption Frequency Meter

If Switch S1 is switched to Absorption, the input of the Display Amplifier is coupled to the direct conversion Mixer. Now additional to the acoustic control DipIt offers an optical control which gives us some quantitative meaning. This can be used to find a maximum of an Bandfilter per example. The strength of the RF at BU5 will be displayed by the LED, its brightness is direct proportional to the strength of the signal. BU5 can be coupled to a DUT by a coaxial cable and a small Cap. Attenuator P1 shout be adjusted to hold the brightness of the LED much below its maximum to make it possible to see small differences in signal level. This Method is a very sensitive variant of the classical Absorbtion measurement. It is extreme useful while optimising / maximizing TX stages. If the frequency of the DUT is not stable, the sweeper can be switched on. In this case the frequency modulated VFO detects the DUT signal which now can be detected and adjusted if the drift is not more then about 8kHz.

Voltage Control

Because a Dipmeter is used periodically, we decided to use Alkaline AA cells instead of accumulators because due to the self-unloading of NiMH cells we assume that DipIt has no power every time you will use it. The 4 Alkaline AA cells give us a Voltage of 6V. Because we need an internal Voltage of 10 Volt, DipIt uses a Voltage converter. T7, T9 and DR8 form the Current Converter, C37/R38 determine the switch frequency. The converter output voltage loads the capacitor C35 via a Schottky–Diod D8. Zener Diode D8 and Transistor T8 clamp the output to 10 Volt. The minimum Input Voltage for the converter is about 4 Volt which gives a ood utilization of the batteries.

Batteries control

To control the status of the batteries, an optical control has been integrated into DipIt. Comparator IC2b compares the divided Voltage (R40/R41) of the regulated 8V output with the voltage of the batteries. If Battery voltage drops below 4,4 Volt, the control LED goes to ON state which indicates that the Batteries are next to die.

Frequency read out

DipIt uses a well known counter which was designed by our friend DL4YHF. Resolution below 10 MHz is 100Hz and above 10 MHz 1kHz which is much better then any other Dipmeter can do. The counter has been designed as a plug in module to make it available for other QRP projects. Because it has an easy programmable additive / subtractive part it can be used for small transceivers with Superhet RX as well.

It's A kit

As all other Designs of the German QRP Club, a kit is available from QRPproject. http://www.qrpproject.de/ QRPproject started shipment of kits on May 15. 2006. Because the extreme high number of orders, from the very beginning the waiting time is about 4-5 weeks. We hope to decrease waiting times soon.

Download the complete Dipper-Schematic here.

Download the englis manual here

Manual addon: Wirinig of the switches:

The DipIt-Kit comes complete with double sided industrial PCB, all parts, an Industrie made Alu Enclosure, all cuts and drills already done. The Counter is included. English manual.

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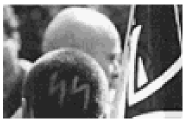
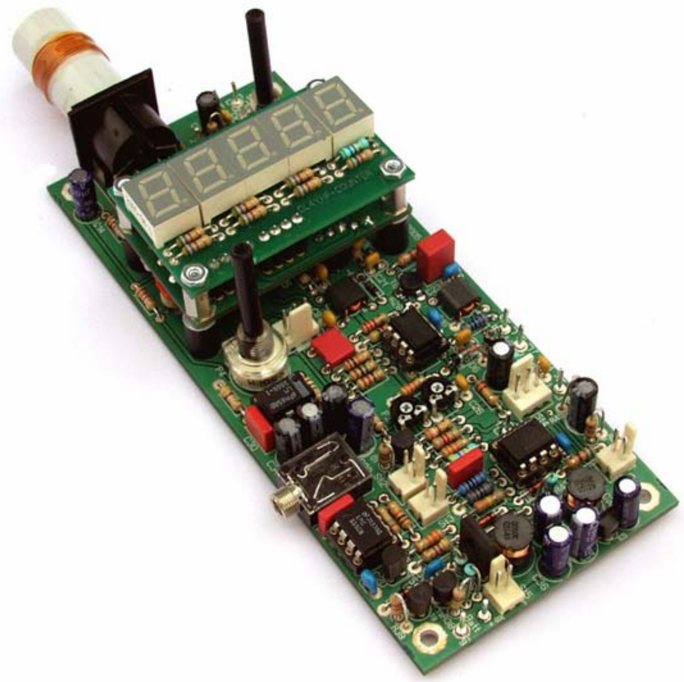


DL-QRP-AG



DipIt, the ultimate Dipmeter

Manual Vers. 1.21

November 22.2007

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„DipIt", the Super- Dipmeter" of German QRP Club DL- QRP- AG

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Kit Realisation: Nikolai Zenker, DL7NIK
Manual-Translation: Pete Meier, WK8S and Peter Zenker, DL2FI

Preface:

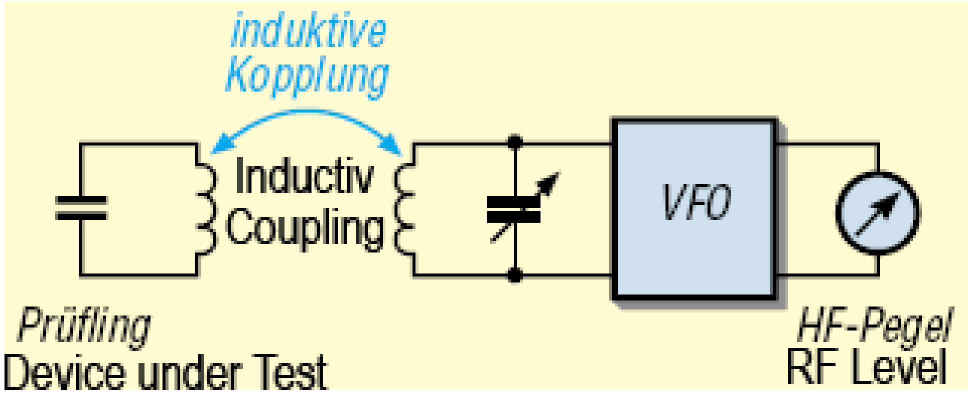
Very often a home brewing radio amateur comes into the embarrassment to measure the unknown resonant frequency of a receiver or transmitter oscillating circuit or to adjust a post Mixer filter to the correct frequency. Such or similar measurement tasks can be done easily with a so called "dipper". The "old rabbits" beyond us know, this instrument used to be the basic equipment of their amateur activity and often it was the only RF measuring tool available when they constructed their noteworthy projects. But using a dipper was allmost forgotten in the course of the commercialization of amateur Radio for times. Now, when homebrewing in HAM Radio has a renaissance, the dipper is more up-to-date than ever. It can help to do lots of sophisticated measurements during homebrewing of Radio Kits at low cost rates and it can eliminate the need to buy much more expensive test equipment if it is well designed. On multiple request of DLQRP AG Club members the author developed a "Superdipper kit" which is equipped with some extra practical additional functions apart from the real basic functions.

Technical data:

- frequency range: 1-42 MHz (divided up into 5 areas by means of plug in coils) VHF / UHF Option with plug in Oscillator
- new highly sensitive "sweep-frequency method"
- frequency indication by 5-digit LED display
- resonance display with a super bright light-emitting diode
- frequency tuning by 10- turn potentiometer
- heterodyne frequency meter with an additional headphone output +BNC input (with attenuator)
-absorption frequency measurement with optical display (LED)
- amplitude stable +7 dBm generator output for peripheral attachments (Antenna ananalyzer and other)
- integrated switching transformerr working with 4 AA batteries
- visual battery voltage control

Basics:

The mode of action of classic dip metres is based on the fact that the amplitude of an L/C oscillator decreases if it is coupled to a resonant circuit working at the same frequency (the dip). If the oscillator is variable and provided with a calibrated frequency scale, then it can be used easily



to find the resonant frequency of an unknown L/C Circuit. To have a broader frequency range and good resolution at the samee time, most Dip Metres use Plug in coils.
To find the resonate frequency of an unknown circuit, the DipMetre Coil usually will be couplet inductive or capacitive to the object to be measured. The actual amplitude of the VFO (or the proportional Grid current if it is a tube Dipper, normaly can be controlled by using an analog Voltmeter.

All previous dipmeter more or less in common show the following weak points

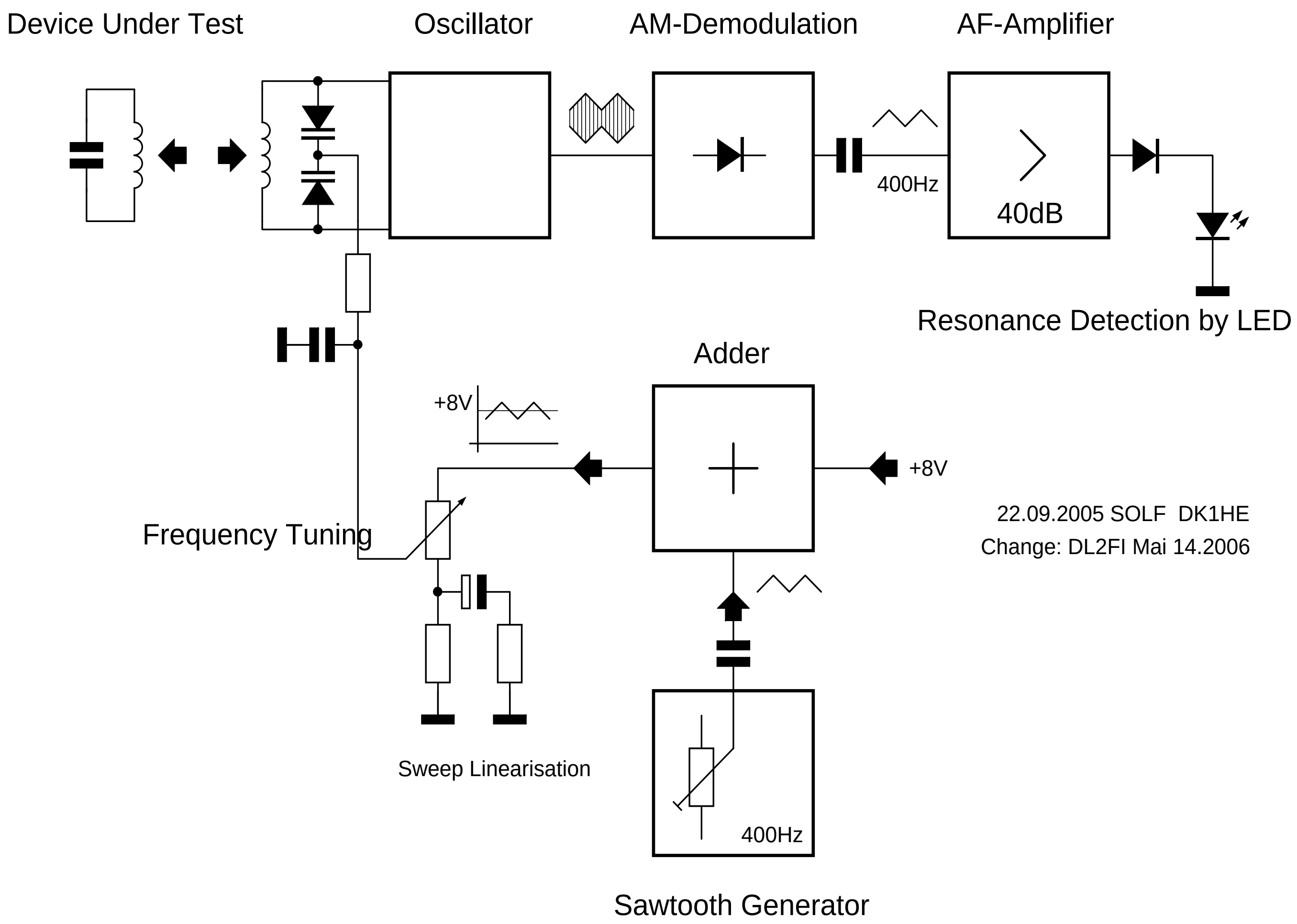
The amplitude of the oscillator changes from the beginning to the end of the tuning range. It strongly dependends on the chosen frequency range. All models have a sensitivity control, which permanent must be regulated to keep the instrument at 2/3 of full scale where eventually a dip coud be seen at its best. At higher frequency it often is impossible to adjust the instrument to 2/3 of full scale.

To achive good acuraccy and avoide detuning of the measured object, the Dip Metres coil alway should be coupled as loose as possible. At the recommended loose coupling however, sensitivity of a normal Dipmeter decreases rapidly. Often the " Dip" more or less only can be suspected then it can be seen.

The "super dip metre" developed by the author avoids problems mentioned above with the following trick :

The heart of the circuit is a varctor controlled VFO. The tuning range is approximately an octave. The normal Tuning Voltage for the Varactor becomes superimposedly with a balanced sawtooth voltage of small amplitude. The result is a balanced frequency modulation (sweeping) of the VFO around the carrier mid frequency. The chosen frequency shift is aproximately +/- 0.2% of the current oscillator frequency. The sweep rate is approx. 400 Hz. The VFO frequency if couppled to an object in resonance "sweeps" over the resonating curve of the examinee now.

DK1HE - " Superdipper " DipIt



The same is carried out manually by the operator at conventional dip metres with the tuning knob but muchl slower !!

The answer of the VFO is a 400 Hz amplitude modulation of its HF output voltage due to fact, that the examinee sucks more or less energie from the VFO depending on the frequency beeing more or less in resonance or not. The modulation depth is deeper, the more exact the oscillator mid frequency agrees with the resonance maximum of the examinee or the more strongly the coupling is carried out. A demodulator circuit stage with a capacitive coupling separates the 400 Hz AC signal. . The Super Dippers display consists of a simple AF Amplifier which amplifies the 400 Hz signal by about 40 dB supplies nad a LED which lightens up proportional to the signal strength after rectification. Amplitude changes can be recognized very cleanly since the light-emitting diode is fed with 400 Hz half waves. Alternativ of course a needle meter can be used if wanted.

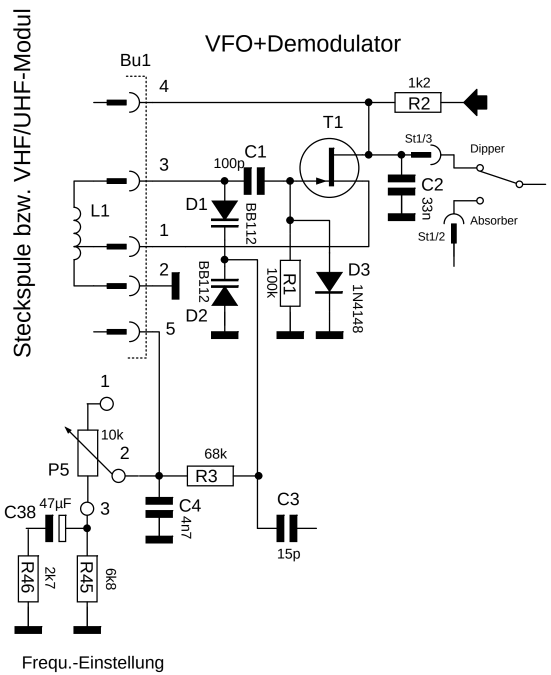
In the measurement procedure described above the absolute HF level of the oscillator plays a subordinate role (only the modulation contents are judged). A Potentiometer for the adjusting of the sensitivity can therefore be dropped.

Since one can almost arbitrarily amplify the demodulated 400 Hz signal as high as you want, this new has Dipmeter design offers a significantly higher sensitivity than all previous equipment. The coupling to the examining object can be carried out extremely loose what is of benefit to a high reading accuracy. (PA coils still can be dipped cleanly from a distance of > 20 cm giving a chance to measure them without any detuning.

Wiring description of the individual circuit stages:

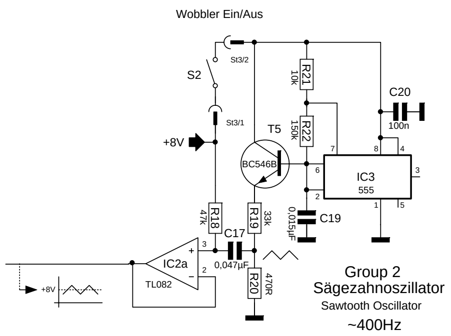
1. VFO:

A Hartley oscillator built up with JFet T1 forms the heart of the circuit. The oscillator circuit consists of the L1 amd tuning diodes D1-D2. By means of the 10 turn Pot P5 the oscillator frequency can varied around by about an octave. By choice of the plug in coil a total frequency range of approx. 1 MHz to 42 MHz is covered in 5 steps. D3 has two functions: 1. it serves for the automatic bias voltage generation of T1 an d2. it works as AM demodulator. R2-C2 form a AF lowpass filter with a cutoff frequency of about 4 kHz.The demodulated 400 Hz AF Signal, which allready has been preamplified by T1 is coupled to the inducation amplifier by C2 / S1.



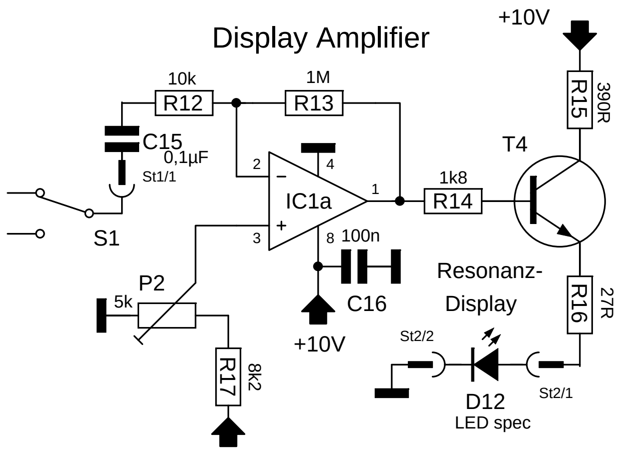
2. Frequency sweep generator:

The timer circuit IC3 forms an R/C oscillator with a balanced sawtooth output voltage. The generated frequency is approximately 400 Hz. The output signal is divided by R19/R20 the an optiml vaue for the frequency swwp operation. IC2a works as adding stage. The sawtooth voltage coupled by C17 is added to the stabilized DC coupled by R18. At the output of the OpAmp now we have an 8V DC with a balancedly superimposed sawtooth. This is feed into tuning Pot P5. R45 defines the VFO-tuning range. C38-R46 and P5 form a voltage divider for the sawtooth quota of the tuning voltage. They also linearize the unlinear Voltage/Capacity curve of the diodesD1/D2 especially in the lower voltage range. By this methode an almost constant sweep shift is obtained over the complete variation area.



3. Indication amplifier:

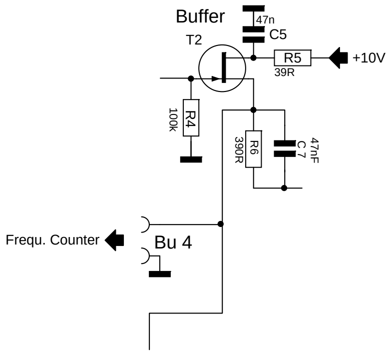
The demodulated 400 Hz signal coming from T1 via selector switch S1 reaches the input of the AF amplifier IC1a. By means of R12-R13 the gain is set to 40 dB. Capacitor C15 serves to isolate the DC quota of the signal voltage. Byt P2 the DC quiescent output level of the OPs is adjusted so that the light-emitting diode D12 (resonance display) just starts "week glowing" without AC signal. The circuit works in addition as a rectifier at this operating

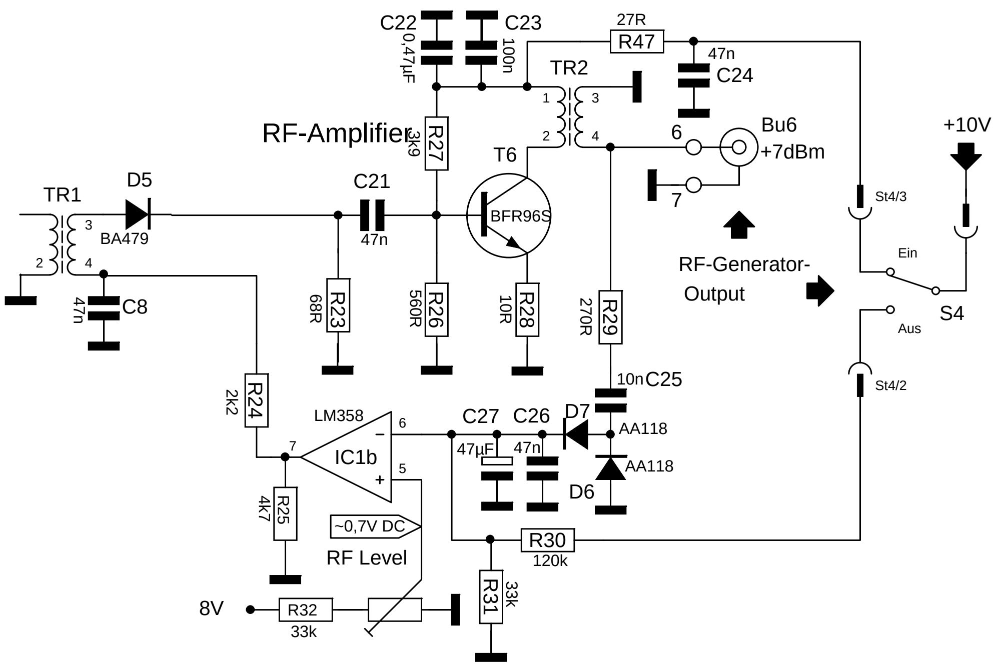


point adjustment. At an available AC signal the positive half waves of the OP output voltage cause a periodical current flow in the light-emitting diode. The brightness is proportional to the signal amplitude. T4 serves for the current load reduction of IC1a. R15 limits the diode current to about 20 mA.

4. VFO buffer stage, Power Amplifier, Regulation Circuit Stage

Capacitor C3 couples the low harmonic VFO signal directly to the following JFET buffer stage T2. The RF Voltage at the low-impedance source is feed into the frequency counter module via connector Bu3 to to display the actual VFO frequency. It serves furthermore than as Local Oscillator (LO) signal for the beat frequency measurement. Impedance transformation is carried out by TR1 to the following output amplifier T6. By means of the counter-coupling resistance





Group 5 Power Output

R28 the stage gain is adjusted to 20 dB. The transformer TR2 transforms the dynamic Collector-Resistance of T6 to the system impedance of 50 ohms. The amplified RF signal can be taken from the signal source output jack Bu6 for individual applications.

To ensured a frequency range and frequency independent output level of 7dBm the circuit around Transistor around T6 is designed as a "VCA" (Voltage controlled amplifier). The actual RF output voltage at Bu6 is supplied about the decoupling resistor R29 to the peak voltage rectifier circuit D6-D7 and after filtering by means of C26-C27 as nominal "Ebit Voltage" passed to the inverting inverting input of IC1b. The non inverting Input is feed with a "Debit Voltage, controlled by variable Resistor P3. PIN-Diode D5 is the "setting device", together with R23 it forms an RF Voltage divider, controlled by the Diode current.

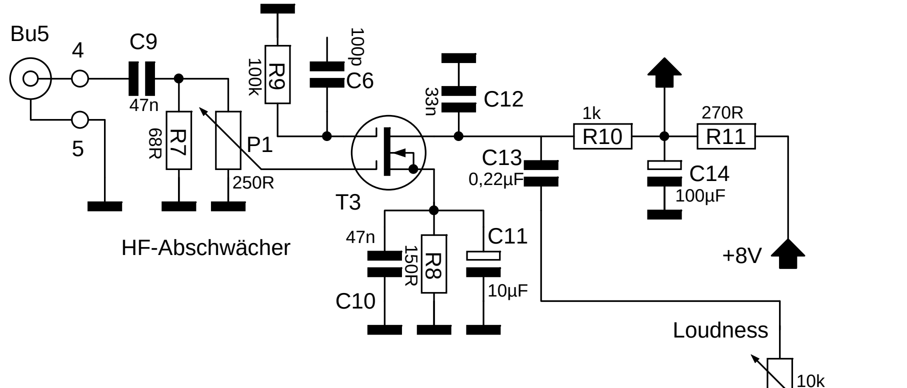
Example:

if the rectified RF Voltage is smaller then the Level preadjusted by P3, the DC output of IC1b gets more positive. By means of R24 the current in Diode D5 increases. This causes an increase of the dynamic resistance of D5. So the RF Voltage at R23 (Input of RF Amplifier) increases until the rectified output equals th Value predefined by P3.

Is the level at Bu6 is too high, the "debit voltage" is higher then the "Ebit voltage". Now the output at IC1b decreases as well as the current in D5. Lower current in D5 causes higher dynamic resistance in D5, so the RF Voltage at T6 also will decrease until the inverting input meets the "Debit Voltage" again.

5. Heterodyne Frequency Measurement:

The "heterodyne frequency measuring instrument" fallen into oblivion long ago is excellently suitable for the frequency measurement of small HF Voltages in the µV area or to the telemetering of unknown signals over an aerial. Integrated in our SuperDipper you find a direct conversion mixer built up with the MOSFET-Tetrode T3. The signal voltage coming from the input jack Bu5 reaches via adjustable reducer P1 the Gate 1 of the mixer stage. The Lo signal coming from T6 is brought to the Gate 2. The difference frequency relevant for the measuring is at the output of T3 with an assessment frequency range of 4 kHz of (Lowpassfilter R10-C12) at the



Group 4 Directconversion
(Zerobeat Frequency Meter)

disposal. The audio amplifier IC4 allows monitoring of th esignal signal to be measured with headphone volume. If Input frequency and vfo frequency are almost all the same, you hear the so called "beat tone". If now vfo frequency is carefully adjusted until the beat frequency is not loger audible (now "zerobeat"), bith the measured frequency and the VFO frequency are exactly identical..

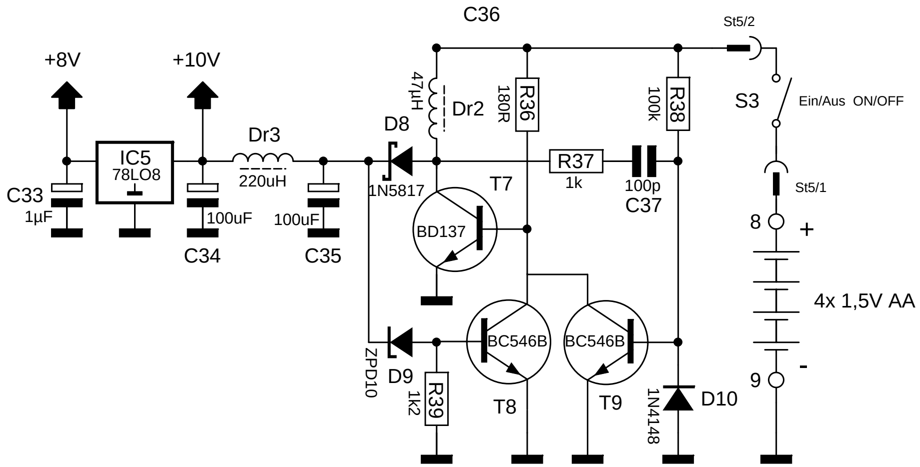
During the measuring described above the Sweep-Generator must be turned off!

6. Absorption Measurement:

If the operation style switch S1 is switched to position "absorber", the input of the indication amplifier is connected to the output of the direct conversion mixer T3. In this mode the visual level, known of the Dipper gets effective in addition to the acoustic assessment of the signal. The amplitude of an HF Voltage fed in into jack Bu5 is announced by a proportional brightness of D12 now. The vfo must be taken to "zerobeat" with the frequency to be measured. The Attenuator P1 should be adjusted so, that D12 never shines with full brightness since otherwise small amplitude changes of the signal voltage cannot be recognized cleanly. This measurement procedure is the more sensitive variant of the well known classic Absorbtion Measurement. With it transmitter oscillating circuits or Bandpassfilters behind TX mixers very easily can be tuned on maximum. If the RF signal to be measured is not frequency stable the Sweeper can be switched on. In this case the now frequency modulated VFO vfo sweeps over a certain area of the drifting measuring frequency and the signal maximum still can be recognized cleanly here too, provided that the frequency instability does not get greater than about 8 kHz.

7. Voltage Supply:

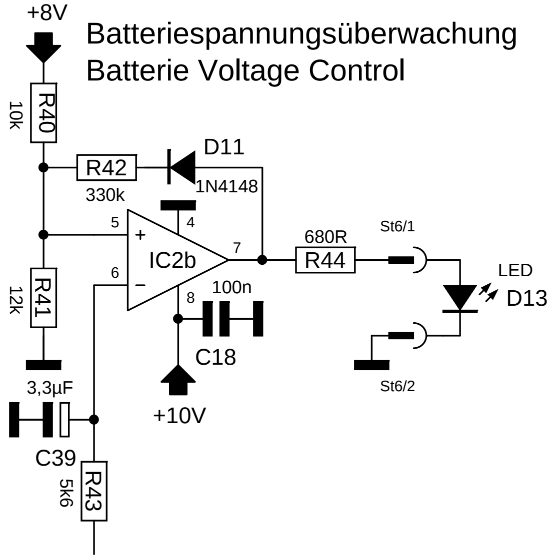
Since a dip metre will be used only sporadically in the amateur radio practice and due to the known the self-discharge problem of modern high



capacity NiMH accumulators we decided to use 4 of cheap AA- alkali manganese batteries which offer an operating voltage of 6 volts)? The internally required 10 volt supply Voltage we produce with a switching transducer. T7 forms a flyback converter together with Dr2 and T9. C37-R38 determines the switching frequency. The transducer output voltage reaches the Schottky switching diode D8 to the filter capacitor C35. The Z diode D9 together with Transistor T8 are limiting the transducer Voltage to 10 volts . The switching transducer works stable as long as the batterie voltage is higher then 4 volts, so the full capacity of the batteries ca be used.. The sieve Dr3-C34 reduces the residual ripple on the 10 volt supply Voltage, the following Voltage regulator IC5 provides the system with the stabilized 8V DC we need at some places.

8. battery voltage control:

To get full control over the batterie status, a visual battery voltage supervision was integrated into the SuperDipper. The Comperator IC2b compares the voltage down shared about R40-R41 (4,4V) with the battery voltage supplied by R43. If the actual Voltage falls below the 4.4 volt threshold, the output from IC2b switches "high" and the approaching end of the battery voltage range signals the light-emitting diode D13.

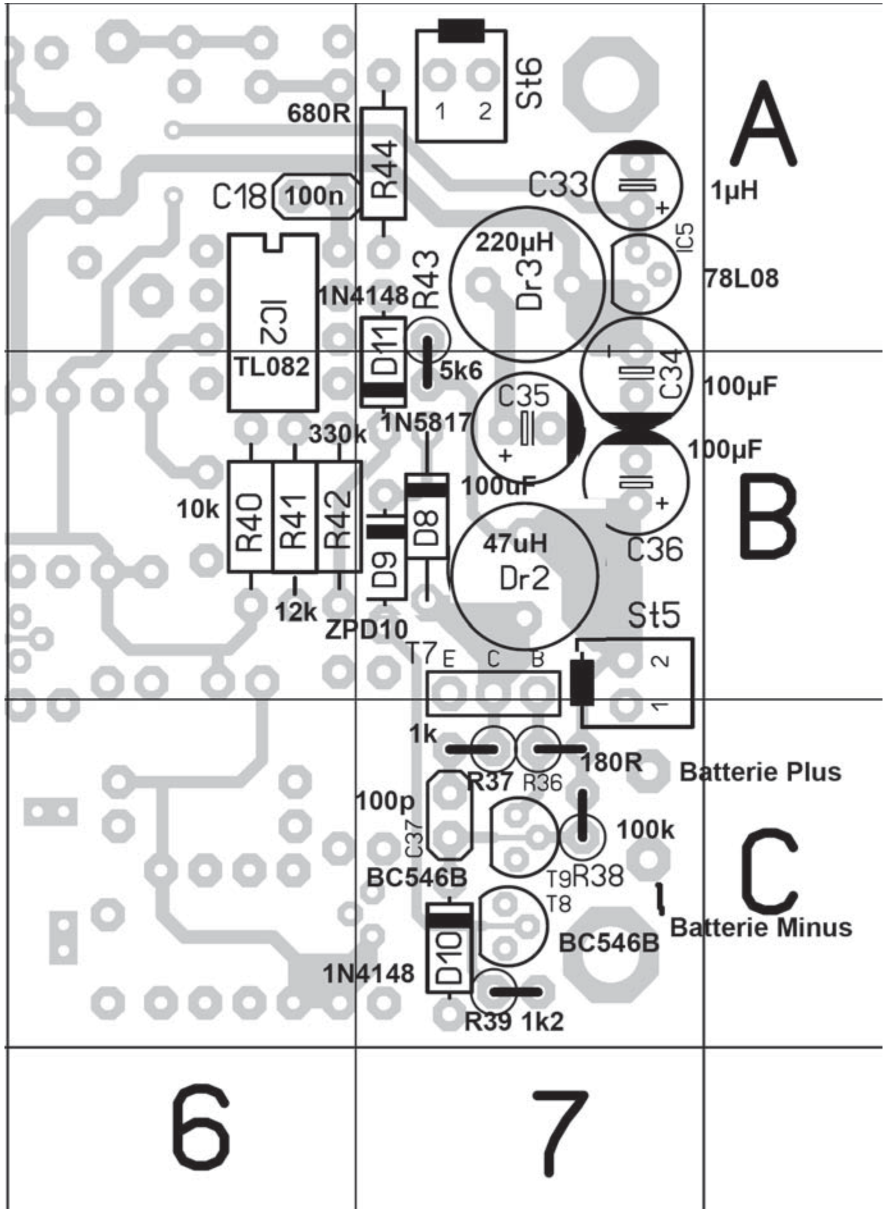


By means of D11-R42 the Komparator gets a hysteresis what a stable function ensures also at battery Voltage

A following AM demodulation stage separates the the 400 Hz AC tone. The display part of DipIt is a simple 40dB AF Amplifier, a rectifier and a superbright LED.

Using this method, the only criteria of detecting resonant devices is the AM-Modulation so the different Amplitude hight of the VFO depending on its frequency is no longer a problem. That fact, that an AM signal can be amplified very easy increases the sensitivity of the dipper dramatically. Coupling between DipIt and DUT can be much looser then with any conventional dipmeter, the dip is absolutely clearly.

Beginning of the structure Building group 1, voltage supply



Beginning here, there are ESD sensitive parts used.

[ ] St6	A/7	**CHANGE!!! ST6 do not install!!!**

[ ] R44	A/7 6	680R
[ ] C18	A/6	100nF
[ ] D11	A-B/7	1N4148 pay attention to situation of the ring-stamp (cathode)
[ ] R43	A-B/7	5,6K
[ ] Dr3	A/7	220uH
[ ] Dr2	B/7	47uH

With the following Elko(electrolytic) be careful how they are installed. The longer leg is the positive pole, the housing is marked on the side with the minus connection mark.

[ ] C35	B/7	100uF rad. Elko
[ ] C33	A/7	1uF rad. Elko
[ ] C34	A-B/7	100uF rad Elko
[ ] C36	B/7	100uF rad Elko
[ ] R40	B/6	10K 1%
[ ] R41	B/6	12K 1%
[ ] R42	B/6-7	330K
[ ] D8	B/7	1N5817
[ ] D9	B/7	ZPD10
[ ] St5	B-C/7	Patch cord receptacle 2-pol, tongue inward!
[ ] R37	C/7	1K
[ ] R36	C/7	180R
[ ] C37	C/7	100pF
[ ] R38	C/7	100K
[ ] D10	C/7	1N4148 pay attention to situation of the tax stamp
[ ] R39	C/7	1,2K

Transistors and ICs are more or less sensitive to ESD. It is however a good exercise with semiconductors to pay attention and adhere to the ESD safety precautions. Use a ESD bracelet or at least touch a bare, grounded surface, before you touch the transistors.

[ ] T8	C/7	BC546B
[ ] T9	C/7	BC546B

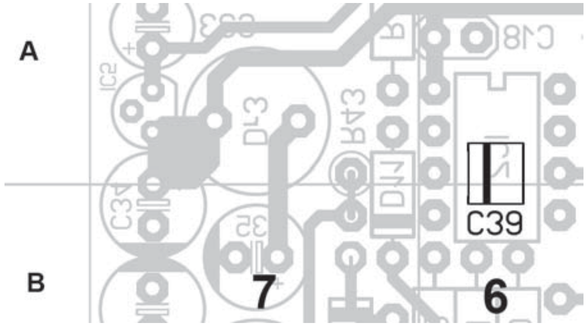
The BD137 is inserted in such a way that the marked side is turned away from the choke/coil and points to the edge of the board.

[ ] T7	B-C/7	BD135 (oder BD137, BD139)
[ ] IC5	A/7	78L08 TO92

Pay attention to the correct installation of IC 2. The notch marks pin 1 (to

the left of the notch) in the bill of material
[ ] IC2 A-B/6 TL082 DIL8

On the lower surface below the IC2 a tantalum capacitor is soldered. The POSITIVE side is marked by a bar with this design (SMD Baugr. B). The bar is clearly seen towards the diode and towards the outside edge of the pc

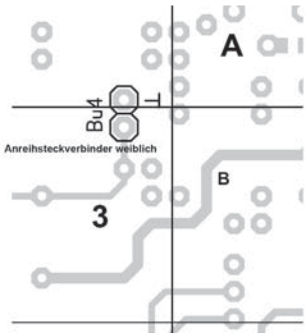


board.
C39 3,3 uF 16V Tantalum SMD

Now socket Bu4 is still missing, to which the display is attached later. It is put on the component side and soldered on the solder side. We use 2 female sockets, which we break-out carefully from the long socket strip.

[ ] BU 4 Contact Strip 2 Pol. A-B/3

For building group 1 now install the LED for the battery monitoring and the switch for the battery.
Take 2 pieces of cable from the hardware parts for the system plug connectors and solder a switch to the wire ends of one cable and the LED to the other cable paying attention to the LED polarity, the short leg is the cathode, it is goes to the plug pin 2.



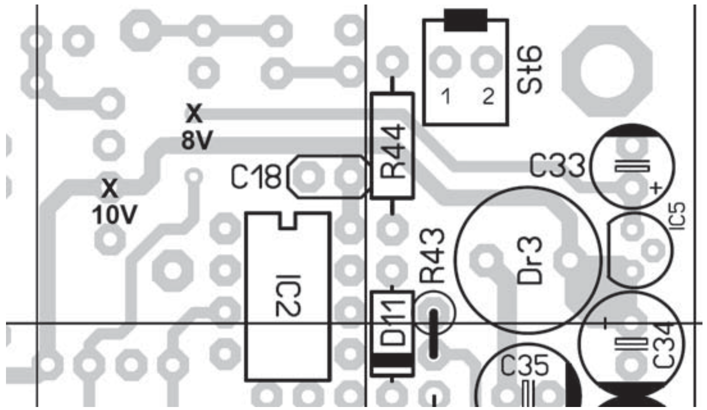
[ ] D13 LED at for cables St6
[ ] S3 Switch S3 at for cables St 5

Do not install/solder ST6 connector to the circuit board. The height of the connector assembly will interfere with closing the case later on.

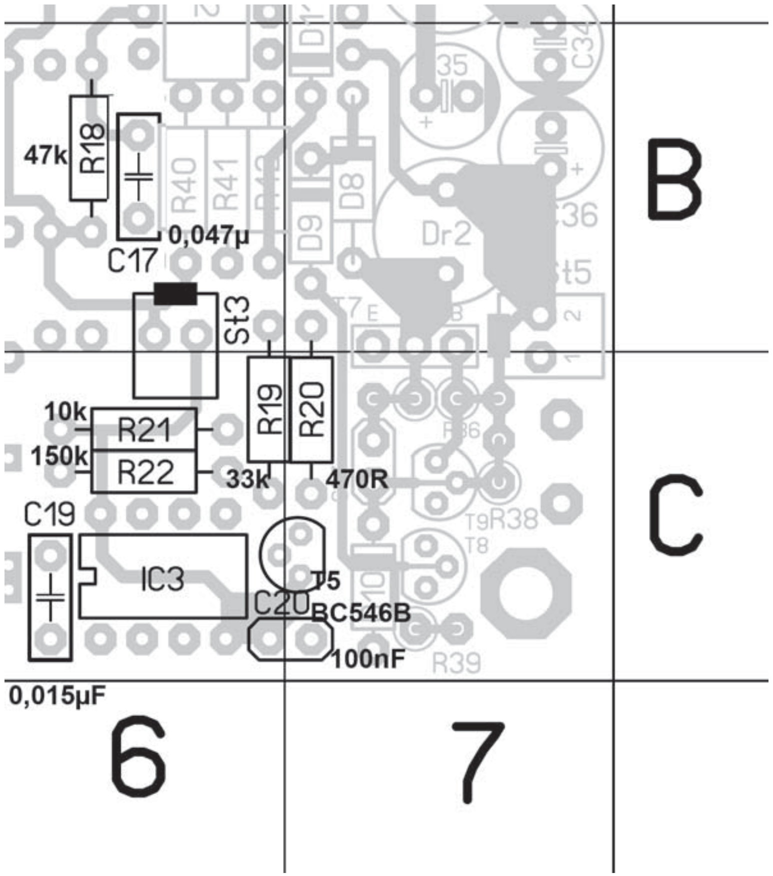
Test of the building group: Connect the battery holder to the PLUS and MINUS battery connections (see bill of material P. 16.)

CAUTION when using a power supply instead of the batteries!!! Do not forget to adjust to **6V**! The transducer does not easily handle 35V from 13V supply and the transistors survive, at 10V it hangs. With laboratory power supply the current limiting may not be adjusted low enough and since the transducer pulls a high starting current damage may occur before the current limiting responds.
Some Batteries and power supplies have very low internal resistance. This may cause the oscillator not so start. To prevent this situation please add a 1 Ohm/1Watt resistor into the +6V power line. Starting September 22. this resistor is included in the kit (as small as the standard resistors, green body).

Attach switch S3 to St5 — Switch the switch on. Measure the voltage at points named X against ground. The 8 and 10V voltages must be achieved. If both voltages are present, you can continue on with the construction of the building group 2.



Building group 2, relaxation oscillator



[ ] R18 B/6 47K
[ ] C17 C6/7 0,047 uF foil capacitor (red)
[ ] St3 B-C/6 2-pole Patch cord receptacle pay attention to orientation of plug
[ ] R19 C/6 33K
[ ] R20 C/7 470R
[ ] R21 C/6 10K
[ ] R22 C/6 150K
[ ] C19 C/6 0,015 uF foil capacitor (red)
[ ] C20 C-6/7 100nF
[ ] T5 C.6/7 BC546B

[ ] IC3 C/6 ICM7555 DIL8 w/ PIN 1 Pay attention to the notch
Connect.switch S2 with cable for plug St3
Solder switch 1xEIN on at cable end.
[ ] S2

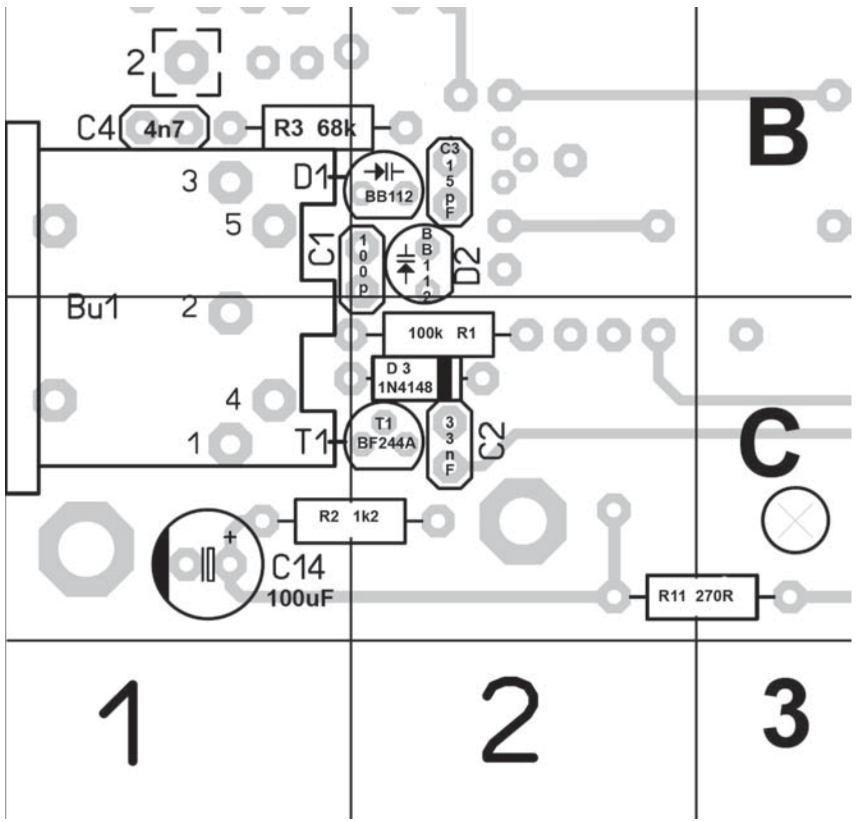
Test Building group 2

Attach Batteries
Switch Batteries ON
S2 is ON

At IC3 PIN 6 temporarily attach a small capacitor in the nF range to feed a pair of headphones. Expect a signal of approximately 400 cycles per second to be heard. Connect the cap to the emiter of T5, the same signal should be heard a little bit quieter.

If that is ok, then proceed with building group 3

Building group 3, oscillator, indicator amplifier



[ ] B-C/1 Bu1 print DIN socket

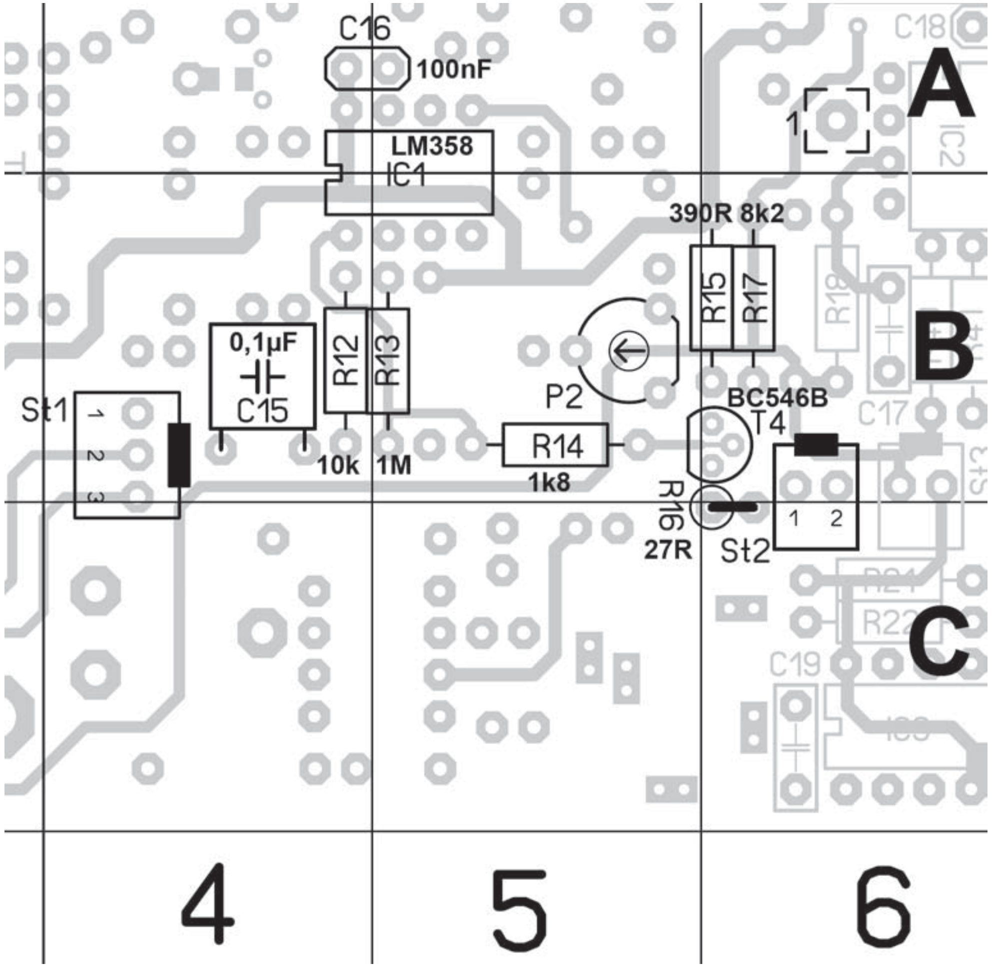
Make sure that the socket is completely flat on the circuit board. Solder only a single socket pin, check the socket position, then solder a second pin and check again. If the socket sits really flat, then solder the remaining pins

[ ] C4	B/1	4,7nF
[ ]	B/1	Solder pin at Position 2
[ ] R3	B/1-2	68K
[ ] C3	B/2	15pF
[ ] C1	B/1-2	100pF
[ ] R1	C/2	100K
[ ] D3	C/2	1N4148

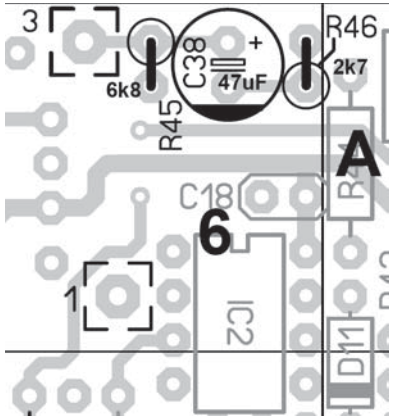
[ ] C2	C/2	33nF
[ ] R2	C/1-2	1,2K
[ ] C14	C/1	100uF, pay attention to polarity !
[ ] R11	C/2-3	270 R

The following two diodes have TO92 housings and 2 legs. The third leg is rudimentarily present and holds the danger to cause a short-circuit between the two legs of the diode. With this in mind, be very cautious to mount the legs so they do not contact each other or touch the wrong circuit board pads.

[ ] D1	B/2	BB112
[ ] D2	B/2	BB112
[ ] T1	C/2	BF244A



[ ] C16	A/4-5	100nF
[ ] St1	B/4	Patch cord, pay attention to tongue
[ ] C15	B/4	0,1uF insert flat to the pc board!!
[ ] R12	B/4	10K
[ ] R13	B/5	1M
[ ] R14	B/5	1,8K
[ ] R15	B/5-6	390R
[ ] R17	B/6	8,2K
[ ] R16	B-C/5-6	27R standing
[ ] ST2	B-C/6	System- Patch cord
[ ] P2	B/5	Trimpot PT6 5K
[ ] T4	B/5-6	BC546B



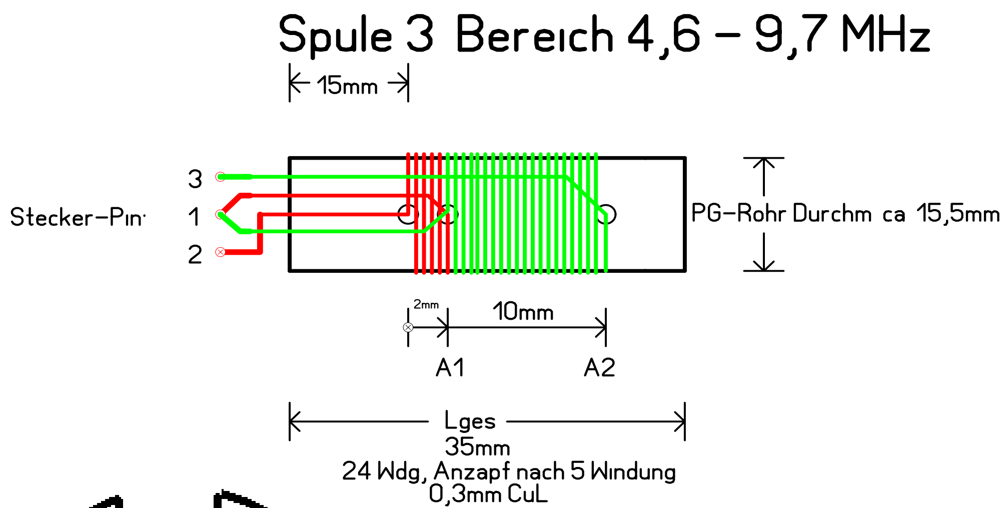
[ ] IC1 A-B/4-5 LM358 observe pin 1 (notch) position
[ ] A/6 Soldering pin Position 1
[ ] A/6 R45 6,8K
[ ] A/6 R46 2,7K
[ ] A/6 C38 47uF
[ ] A/6 Soldering pin on Position 3

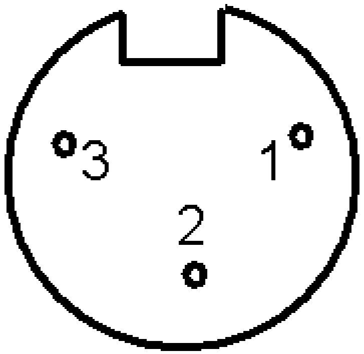
Switch S 1 must be soldered to the 3 wires the ST1 plug.
[ ] S1 switch

[ ] Solder three wires, each about 10cm long to the three connections of the 10-turn potentiometer. Solder one of the solder nails sleeves to the end of any wire.
[ ] Connect the the solderpin sleeves to the responding solder pins. Attention We get different Pot dypes from the supplier, the numbers on the pot do not allways correspond to the solder PIN number. Pin number 2 MUST be connect to the middle connector (variable) of the pot.
[ ] P5 10K 10-Gang-Pot

Solder the 5mm red LED to the two wire ends of the plug St2. The cathode (short leg) attaches to pin 2
[ ] D12 LED
In order to be able to test the building group 3, only one of the 5 Dipper coils must be made. The Dipmeter coil uses a 15.5mm plastic (water) pipe as it’s coil form. The pipe diameter can differ from make to make and the dielectric constant of the spool has a certain influence particularly on the higher frequencies. The data listed (frequency range) is approximate and may vary somewhat. The number of the coils may not be sufficient to completely cover entire frequency range. However, with use of the DipIt frequency counter this will not be a problem.

When making the coils measure from the lateral-end of the 15mm coil form to where you will drill the holes for the winding wire. (see Dimensional drawing).

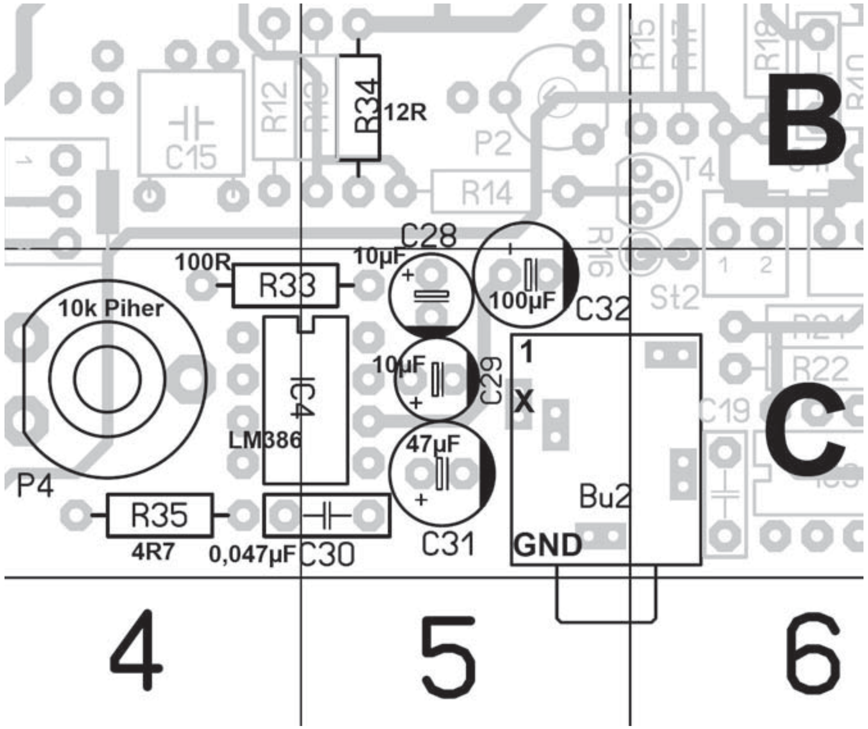




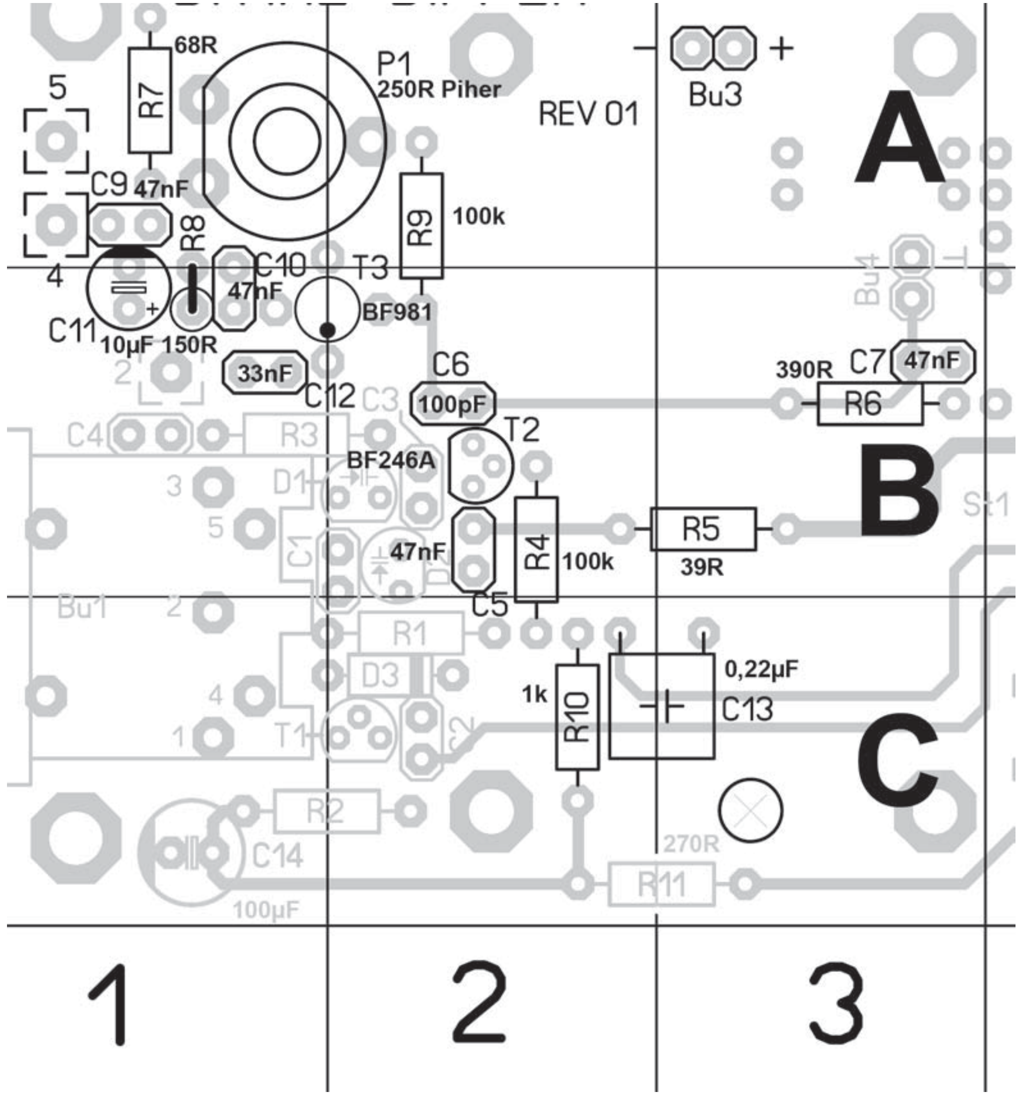
Spule=coil bereich=range stecker=plug
The enameled wire should be wound evenly with each turn close to the next turn. The wire ends should be kept short then soldered to the pins of the plug base. The drawing here shows the soldering pins of the plugs as seen from the solder side. These plugs are part the 5 pin male connectors provided in the kit. You may discard the metal shields and molded covers from these connectors.

Attach the pipe after soldering the base plug. Two differently methods can be used:
1. The plug base fits quite snuggly up to chamfers into the pipe, but one can press it in with the hand without tools. If the pipe sits straight on the base, then the connection can be durably fastened later with some of the two-component adhesives(epoxy).
Actualy we ship two different types of pibes due to some shipment problems of our supplier.
Type 1 has an inner diameter which is a little wider then the black socket. Before glueing the black socket into it, adjust it with 3 small pieces of wood or something similar to sit in the middle of the pipe´s diameter. Glue it to its position with epoxy.

Type 2 has a inner diameter which is a little bit smaller then the diameter of the black socket. One can gently heat up the pipe with a heat gun or a hair dryer. The plug base can now be pushed into the pipe up to chamfers. After the pipe sits and cools off the plug base fit will be quite snug, we recommend, nevertheless, the additional use of some type of adhesive. Now take the Dipmeter with the new coil installed and with the help of a receiver tune and listen for a signal. It should lie somewhere between 5 and 10 MHz and you should hear a very strong signal. If you found it, then the oscillator swings. Put the coil aside, it will be completed and aligned after the Dipper is completely built. Assemble now the counter and the indicator boards. You will repeat this test again with the added counter, after completing building group 4.



[ ] R34	B/5	12R
[ ] R33	C/4-5	100R
[ ] R35	C/5	4,7R
[ ] P4	C/4	10K
[ ] C30	C/4-5	0.04 uF Foil condenser (red)
[ ] C31	C/5	47 uF rad. Elko
[ ] C29	C/5	10 uF rad. Elko
[ ] C28	C/5	10 uF rad. Elko
[ ] C32	B-C/5	100 uF rad Elko
[ ] Bu2	C/5-6	**!! Change: Socket do not install!!!**
[ ] IC4	C/4-5	LM386N-1



[ ] R7	A/1	68R
[ ] C9	A/1	47nF
[ ] C11	A-B/1	10 uF rad. Elko
[ ] R8	B/1	150R
[ ] C10	A-B/1	47nF
[ ] C12	B/1	33nF
[ ] R9	A-B/2	100K

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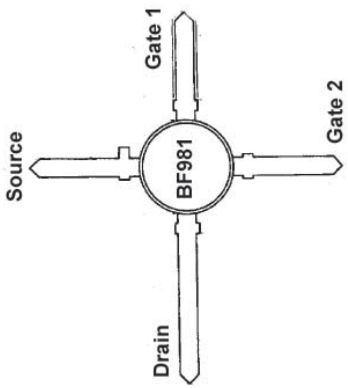
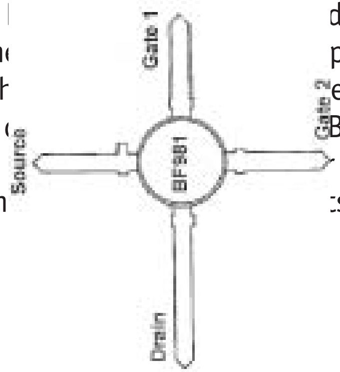
[ ] P1	A/1-2	250R
[ ] C6	B/2	100pF
[ ] C5	B/2	47nF
[ ] R4	B-C/2	100K
[ ] R5	B/2-3	39R
[ ] R6	B/3	390R
[ ] C7	B/3	47nF
[ ] R10	C/2	1K
[ ] C13	C/2-3 0	,22uF Foil capacitor (red) lying flat
[ ] Bu3	A/3	2 pole female socket, which we break-out

carefully from the long socket strip. Solder from the solder side.



Now the dual gate MOS T3. The BF981 is very sensitively to electrostatics, thus consider ESD Measures! The design shows those Arrangement of the Pins as one see sees,from above the dual gate MOSFET. d the position of th picture here clearly sh e case of the BCR all 4 Bend all 4 Pins carefully away (away from th ts place and solder it.

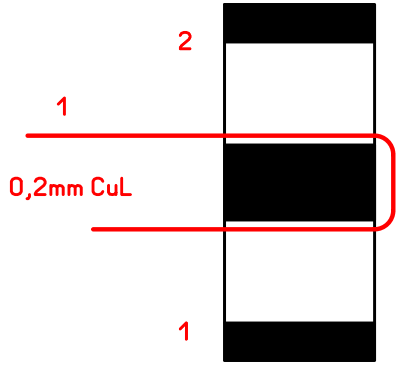


[ ] T3	A-B/1-2	BF981
[ ] T2	B/2	BF246A
[ ]	A/1	Soldering pin up Position 4 and 5

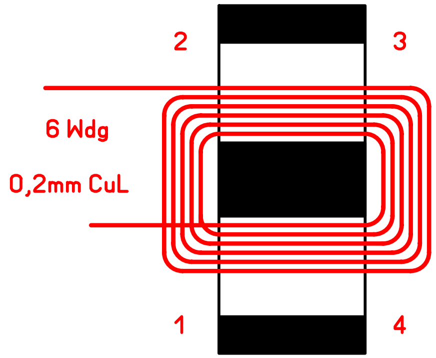
So that building group 4 functions correctly, the transducer TR1 must be inserted.

Winding guidance transducer TR1

Transformer 1 is wound on a double hole core, which among us we jokingly call pig nose. Put the pig nose down in such a way in front of you that the two holes run from left to right. Mark the left side with Nailpolish or other coloured laquer , so that you can again recognize this side later, this side will become the primary Coil. TR 1 receives primarily 6 Turns 0,2mm CuL and secondarily 3 Turns 0,3mm CuL. Cut off a 25cm long piece of that 0.2 mm wire and thread it through the Pig nose, as shown in the picture. Keep

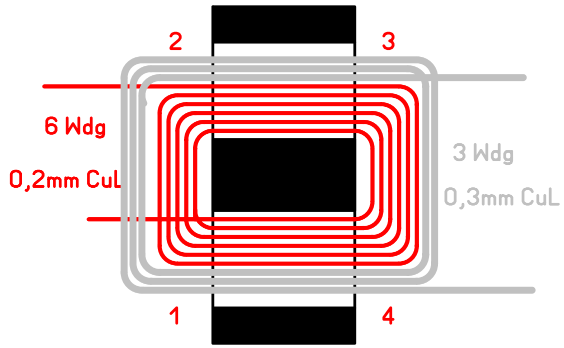


the winding somewhat loose. Pass the wire through the top hole (from left to right)and down through the lower hole (right to left) as shown on the left. This is the first turn.



Now continue the wind back up to and through the top hole (right to left) then down again and through the lower hole (right to left) Turn 2 is finished. Do not pull the wire too much over the edges, the lacquer finish on the wire is very thin.. Contine winding in this fashion with turn three, four, five and six and this completes the primary winding.

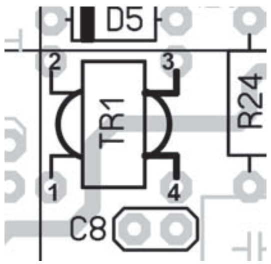
Still the secondary winding is missing. The secondary winding receives 3 turns from 0,3mm CuL. So that the installation is simpler, our technical designer put on TR1 in such a way that the secondary winding is attached exactly on the side lying opposite. Take a 12 cm long piece the 0,3mm of wire, and lead it carefully from right after left by the upper hole and from left to right by that lower hole again back. The first turn is finished. Repeat this step for turn 2 and again for Turn 3. Remember to keep the windings somewhat loose.



In the next step it is important to completely remove the lacquer insulation from the wire ends. That can be done best with „the Blob“ method. The lacquer decomposes with 350 degrees C soldering iron

temperature. With the Blob method, bring the wire into a thick drop of melted tin solder on the soldering iron point. Start directly behind the ferrite body, keep the wire inside the hot Blob on the soldering point and slowly move the wire to its end. This method eliminates the back and forth scrape to remove the lacquer. One recognizes the beginning of the decomposition process by the ascending Smoke. In this phase move the soldering iron slowly toward on the wire end. As the lacquer burns off, the wire tins at the same time. Use a magnifying glass to determine whether the wire is properly tinned.

The transformer can be now installed. Install it exactly as shown, here and drawn on the pcb. Thread those four wire ends into the holes 1 to 4. Pull the transformer by the wires taut carefully against the board. Check whether with all four tinned wires sit in place within the plated-through holes. The transformer should now lie symmetrically as possible between the 4 holes. If everything is correct, then solder the four wire ends as you hold the transformer in place. After completion of the soldering procedure ensure the transformer lies flat against the board. If it is loose heat the four soldered connections in succession and pull the wires taut.

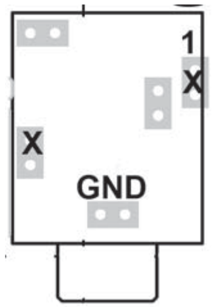


[] TR1 B/4 mini double hole core primary
6 Wdg 0,2mm CuL secondary 3 turns 0,3mm CuL

For the preparation of the building group test solder a 5cm long piece of RG174 coax cable on to the BNC socket BU5. To the other end of the coax cable solder a 2-plug female socket for connection to soldering pins 4 and 5 at (A/1) pin 5 is ground, pin 4 is the center conductor.

[ ] Bu5 BNC

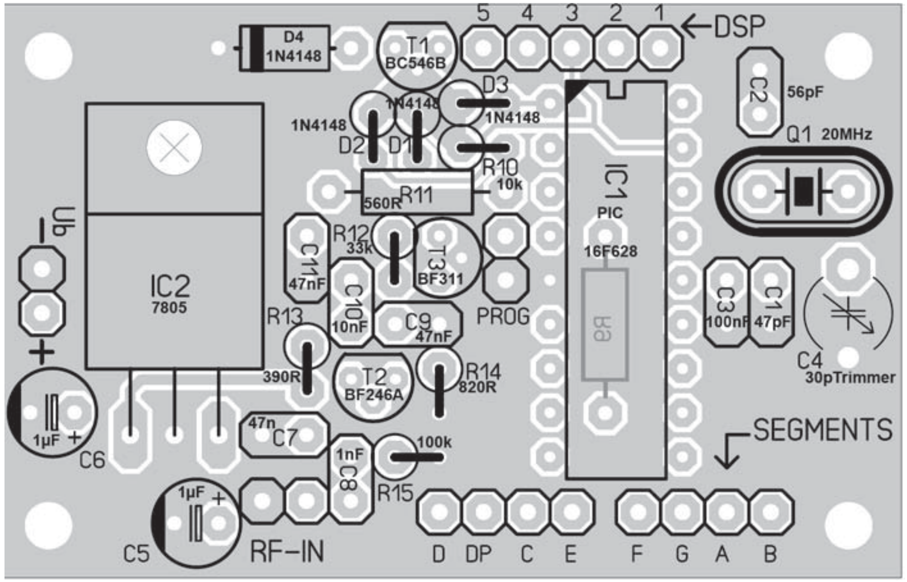
The Stereo socket was originally to be installed on the circuit board. After production of the Dipper cases we discovered however our final design wasn't quite right. We did ourselves a favor and moved the socket off board. The Stereo socket now becomes connected by wires to the original circuit board location right beside the battery holder at the end of the dipper housing. The housings of this series will not have a hole in the side panel. Connect the wires to BOTH points marked „X“ and GND as shown in the layout plan in the picture. Use two twisted wires.



Test building group 4: Attach the battery at the Dipper. Put the coil into the socket for the coil. Put the 10 turn potentiometer to his place, switch on the Dipper. Switch the oscillator off. Switch the Dipper to absorbers. Connect an antenna to Bu5. Plug in Stereo headphones at BU2 set the Volume Pot to the clockwise direction. Place the Attenuation Pot P4 in center position.

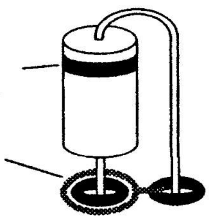
If you turn volume potentiometer up now slowly, then you should hear some broadcasting stations. The Dipper works now like a direct superheterodyne receiver on short wave within the range of the coil being used. Naturally it does not have a much selection, and it you will hear overlapping signals. In our attempts with DipIt prototypes and using a Z-match we heard CW and SSB QSOs without problems.

Frequency counter and announcement



Put the plate down before you in such a way, as seen on the design, so that you can always orient yourself. Do not insert the contact strips yet, you some characteristics to consider. Solder R 9 as the first the resistance. You see it here on the design (as writing in a mirror) drawn inside the outline of IC 1, that means, it belongs on the solder side of the plate.

[ ] R9 10k Install on the solder side and solder on the component side. Cut the Pins off after soldering very close to the soldering plates. The remaining parts are installed normally from the component side. Begin in the left, upper corner. All parts must be installed close to the board otherwise the will be problems later when plugging the boards together.



[ ] D4 1N4148 - It makes sure that the Band mark (cathode end) is oriented as in the design.
[ ] D2 1N4148 Upright. With standing diodes the band stamp shows the cathode upward and the diode body is mounted where the circle is drawn..
[ ] D1 1N4148 standing, exactly the same as D2
[ ] D3 1N4148 standing, the same as D2/D3
[ ] R10 10k install, likewise standing

[ ] R11	560R	lying
[ ] C11 4	7 nF (473)	
[ ] C10	10 nF (103)	
[ ] R12	33k (possibly later up T3 UCE 2,5V adjust)	
[ ] C9	47nF (473)	
[ ] R13	390R	
[ ] R14	820R	
[ ] C7	47nF	
[ ] C6	1uF Elko, respect polarity long leg = PLUS	
[ ] C5	1uF Elko, pay attention to polarity	
[ ] C8	1nF (102)	
[ ] R15	100k	
[ ] C2	56pF	

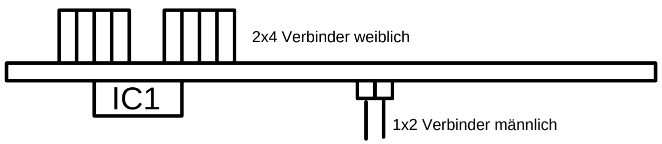
[ ] Q1 20 MHz quartz. Place two cut off resistor leads under the crystal to support the assembly a small distance up from the circuit board. This space will prevent the tin solder from creating a short-circuit between crystal and printed circuit board. <u>Do not forget to pull the wires out again after soldering.</u>

[ ] C3	100nF	(104)
[ ] C1	47pF (47p, 47j)	
[ ] C4	30pF foil trimmer	

Now the base for the microprocessor. Make sure that the notch in the base is oriented in such a way, as seen in the design.
[ ] Socket IC1

Sectional drawing, part facing downward, seen by the broadside
2x4 link female
1x2 ink male Connection sockets are installed on both sides of the display board.. They must make the connection to both the motherboard and to the dis-

Schnittzeichnung, Bauteile nach unten ,von der Breitseite gesehen

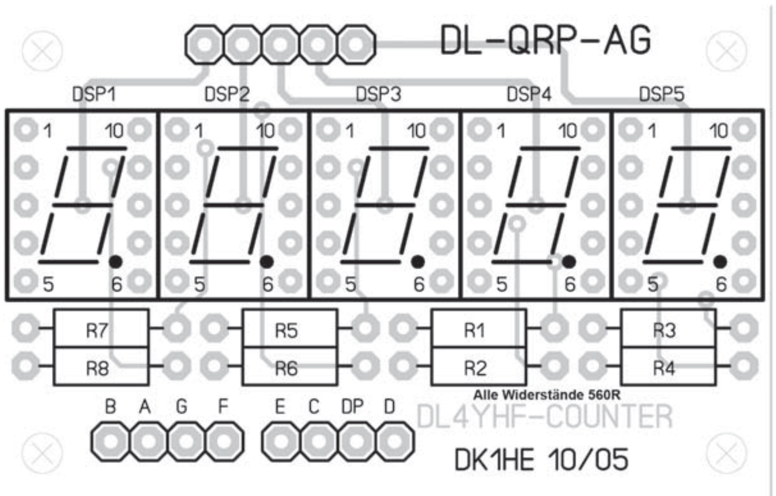


play board. It best done if one builds, aligns completely the two boards together using the plug connectors and enclosed spacers before soldering. For the connection to the display we take the female links.
Install counter plate one Since hanging, thus with the parts to the Haup-platine showing the. The 1x5 and 2x4 link are installed on the solder side and soldered on the component side. Make sure that the links stand as perpendicular to the circuit board as possible. Solder only one pin, align the group and then solder the remainder.
Solder on the component side:
[ ] Link 5.4.3.2.1 (female)   [ ] link D, DP, C.E (female)
[ ] link F, G, A, B (female)

Now the two links to the motherboard. They are installed on the component side and soldered on the solder side. Pay attention again to install it exactly perpendicularly.
[ ] Link Ub (male)   [ ] link RF-IN (male)

Install the remaining semiconductors:
[ ] T1 BC546B   [ ] T2 BF2546A   [ ] T3 BF311
The Voltage Control IC2 = 7805 generally speaking TO220 housing. Now the Processor can be put into the base. Remember, this part is very sensitive to electrostatics, pay attention to the ESD rules.   **[ ] PIC 16F628**

That was the counter, now the display board must be soldered before we



can test everything together. Here there are only few parts. Begin with the resistances. The component side has the label DL4YHF :

[ ] R1	560R	[ ] R2	560R
[ ] R3	560R	[ ] R4	560R
[ ] R5	560R	[ ] R6	560R
[ ] R7	560R	[ ] R8	560R

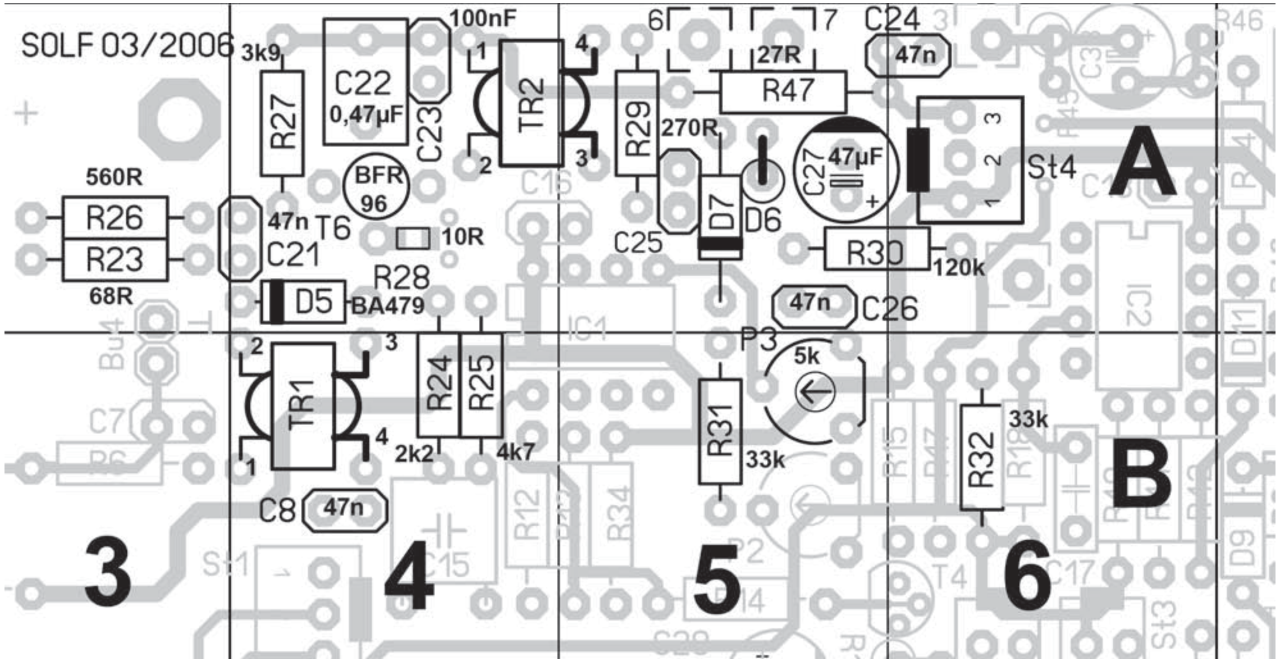
Now the 5 pieces of seven segment displays. Do not insert them upside down. You will see a decimal point on the bottom right of each announcement. Place a display unit into the circuit board, as shown in the design. Press the announcement firmly against the circuit board while soldering and solder only two pins diagonally opposite each other. Check whether the announcement really mounted flat, and correct if necessary, by re-heating the two soldered connections. Then solder the remaining pins. Proceed with all 5 diplay units in accordance with this method.

[ ] DSP1
[ ] DSP2
[ ] DSP3
[ ] DSP4
[ ] DSP5

Now the links. All three connector groups are installed on the solder side and soldered on the component side. Since they connect to the counter board and you installed female links there, logically you must use now use male connectors. Again make sure that they sit accurately perpendicular.

[ ] Link 5 pin (male)
[ ] Link 4 pin (male)
[ ] Link 4 PIN (male)

You can temporarily put the three plates together now. The motherboard on the bottom, whereupon the counter board (parts side towards the motherboard) and on the top the display board (announcements upward). If you repeat the building group 3 test now, you will have a digital frequency display.



[ ] D6 A5 AA143, GA103 or similar.
With standing diodes always the Cathode (banded end upward) and put the body where the circle is drawn in the plan.

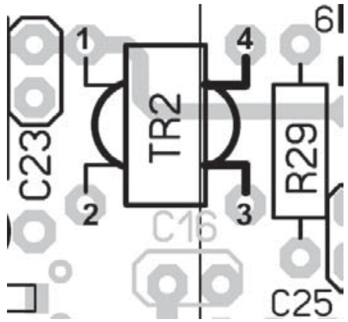
[ ] C25 A/5 10nF
[ ] C24 A/5-6 47nF
[ ] C27 A/5 47¼F
[ ] St4 A/6 System- Patch cord
[ ] R30 A/5-6 120K
[ ] C26 A/5 47n
[ ] R31 B/5 33K
[ ] P3 B/5 5K Trimmpot
[ ] R32 B/6 33K

Now transformer TR2. It is wound exactly the same and inserted, as it was described with Tr1.

Building group 5

[ ] R26 A/3 560R
[ ] R23 A/3 68R
[ ] R28 A/4 10R
The only small SMD part, installs in the middle in the field. Please solder only on the right side (left side unsoldered), so that the hole for T6 is not clogged by solder tin.
[ ] R27 A/4 3,9K
[ ] C22 A/4 0,47uF Foil condenser
[ ] C23 A/4 100nF
[ ] C21 A/3-4 47nF
[ ] D5 A/4 BA479
[ ] C8 B/4 47nF
[ ] R24 B/4 2,2K
[ ] R25 B/4 4,7K
[ ] R29 A/5 270R
[ ] R47 A/5 27R
On the board with DR1, designates replacement)
[ ] D7 A/5 AA143, GA103 or similar.
Caution, the glass body breaks easily!

[ ] TR2 A/4-5 mini double hole core primary 6 Wdg 0,2mm CuL secondary 3 turns 0,3mm CuL
Now transistor T6. This is very sensitive to ESD. Insert T6 so that you can see the writing from above and carefully bend the three Pins downward perpendicularly. Set T6 into the three holes, the writing must remain readable otherwise the transistor is mounted backwards.



[ ] T6 A/4 BFR96S
Now do not forget, to solder the left side of the SMD transistor R28!!!!
Install the two soldering nails in positions 6/7
[ ] Soldering nail A/5 Position 6
[ ] Soldering nail A/5 Position 7

Temporarily solder two wires to ST4 from the switch S4. Solder a 5cm long piece of coax cable to a Phono socket. Solder the other end to the soldering nails at positions 6 (center conductor) and 7 (ground).

Test building group 5

Attach the battery and all switches used so far to DipIt. Put the frequency coil already manufactured into the base. Connect Bu6 (HF generator output) to a dummy load (can be small dummy load as we produce only QRPppp, 7dBm).

Switch the Dipper on.
Switch the relaxation oscillator out (S2)
Switch the mode selectors to „Dipper „

Measure with a high impedance voltmeter the DC voltage at IC1 pin 5 and adjust it with the trim potentiometer P3 to as close as possible to 700mV. (For this manual: exact value still to be determined). Thus the output of the generator is adjusted to +7dBm according to 500mV EFF HF at 50 ohms. (D6/D7/C26/C27 form a HF probe, which changes the HF voltage into DC voltage as it heads to the automatic control loop, which keeps power output constant.)
Alignment work:

There are actually only three places, which can be adjusted:

1. P2 in the indicator amplifiers building group. P2 is adjusted in such a way that the breakdown voltage of the diode without control is reached by the Dipper. In addition the coil is taken off and P2 adjusted in such a way that the LED just „visibly glows“. The whole naturally in position „Dipper“ and „Oscillator“

2. The Dipper With a counter it does not depend on a few Hertz. One can adjust the indicated frequency by means of the trimmer C4 on the counter board in comparison to a reliable external frequency source

3. The +7dBm amplifier. The power output of the amplifier is limited using the trim potentiometer P3, sees accompanying description.

4. For sensitivity increase the oscillator can be increased somewhat, if R15 is made smaller on by approximately15kOhm. . It is enough to solder a 27k resistance parallel to R19.

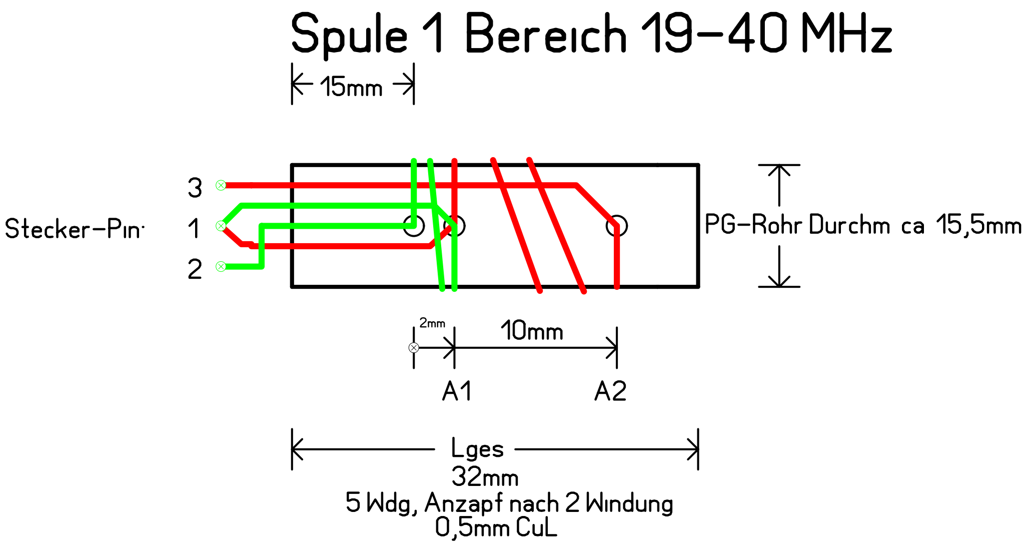
Production and calibration of the coil spool.

The measuring rangei is overlapping, starting with low frequency with coil 1 and continues upward. You hav already manufactured coil 3. The Dipmeter coil uses a 15.5mm plastic (water) pipe as it's coil form. The pipe diameter can differ from make to make and the dielectric constant of the spool has a certain influence particularly on the higher frequencies. The data listed (frequency range) is approximate and may vary somewhat. The number of the coils may not be sufficient to completely cover entire frequency range. However, with use of the DipIt frequency counter this will not be a problem.

After completion of the coil, coat the coil with a thin coat from eagle owl pluses or similar adhesive to protect against environmental influences. The plug is stuck into the pipe and slid up to chamfers.

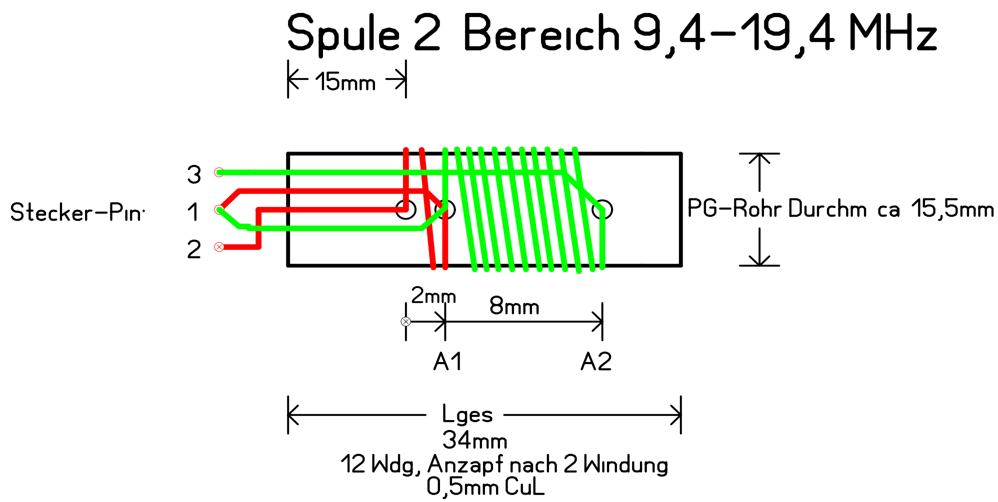
One can gently heat up the pipe with a heat gun or a hair dryer. The plug base can now be pushed into the pipe up to chamfers. After the pipe sits and cools off the plug base fit will be quite snug, we recommend, nevertheless, the additional use of some type of adhesive.

Reel 1:19 MHz-40MHz



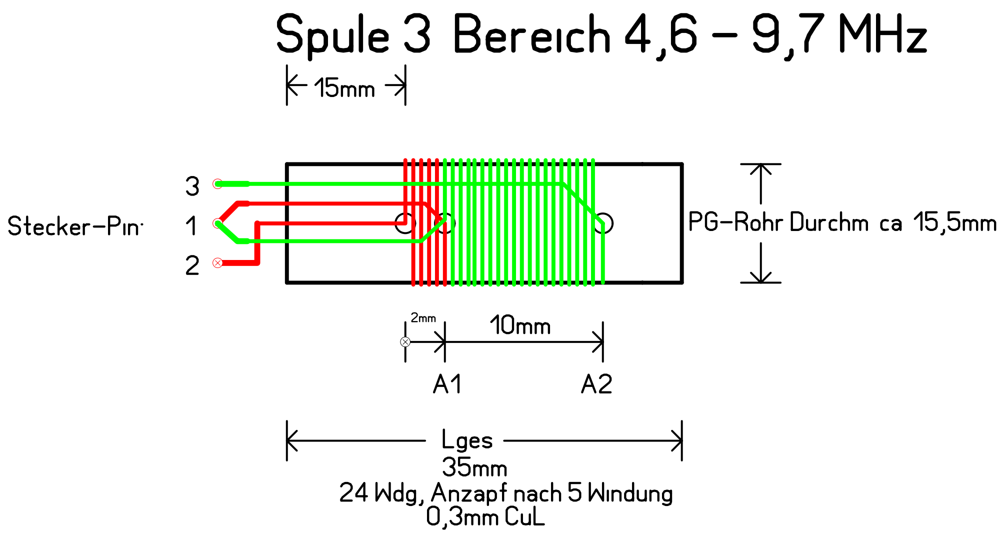
Lges= 32mm/A1= 2mm/A2= 10mm Total total: 5 Wdg 0.5 mm of CuL, tap with 2. Spread the turns to result in a max.-upper frequency of approx. 40 MHz. Measure this with the Dipmeter counter.

Reel 2:9,45 MHz-19,4MHz



Lges= 34mm/A1= 2mm/A2= 8mm
Total total: 12 Wdg 0,5mm CuL, tap with 2.
Spread the turns of the cold end. The turns must be spread in such a way that the highest adjustable frequency lies somewhat higher than the lowest frequency of coil 1.

Reel 3:4,65 MHz-9,73MHz
Lges= 35mm/A1= 2mm/A2= 10mm
Total: 24 Wdg 0,3mm CuL, tap with 5. Turn of the cold end
The turns must be spread in such a way that the highest adjustable frequency lies somewhat more highly, as the lowest adjustable frequency of coil 2.



Coil 4 and 5 are wound in the same manner, we did not not make drawing for coils 4 and 5 because it wasn't clear due to the high numbers of turns.

Reel 4: 2,44 MHz-5.05MHz
Lges= 45mm/A1= 4,5mm/A2= 23mm

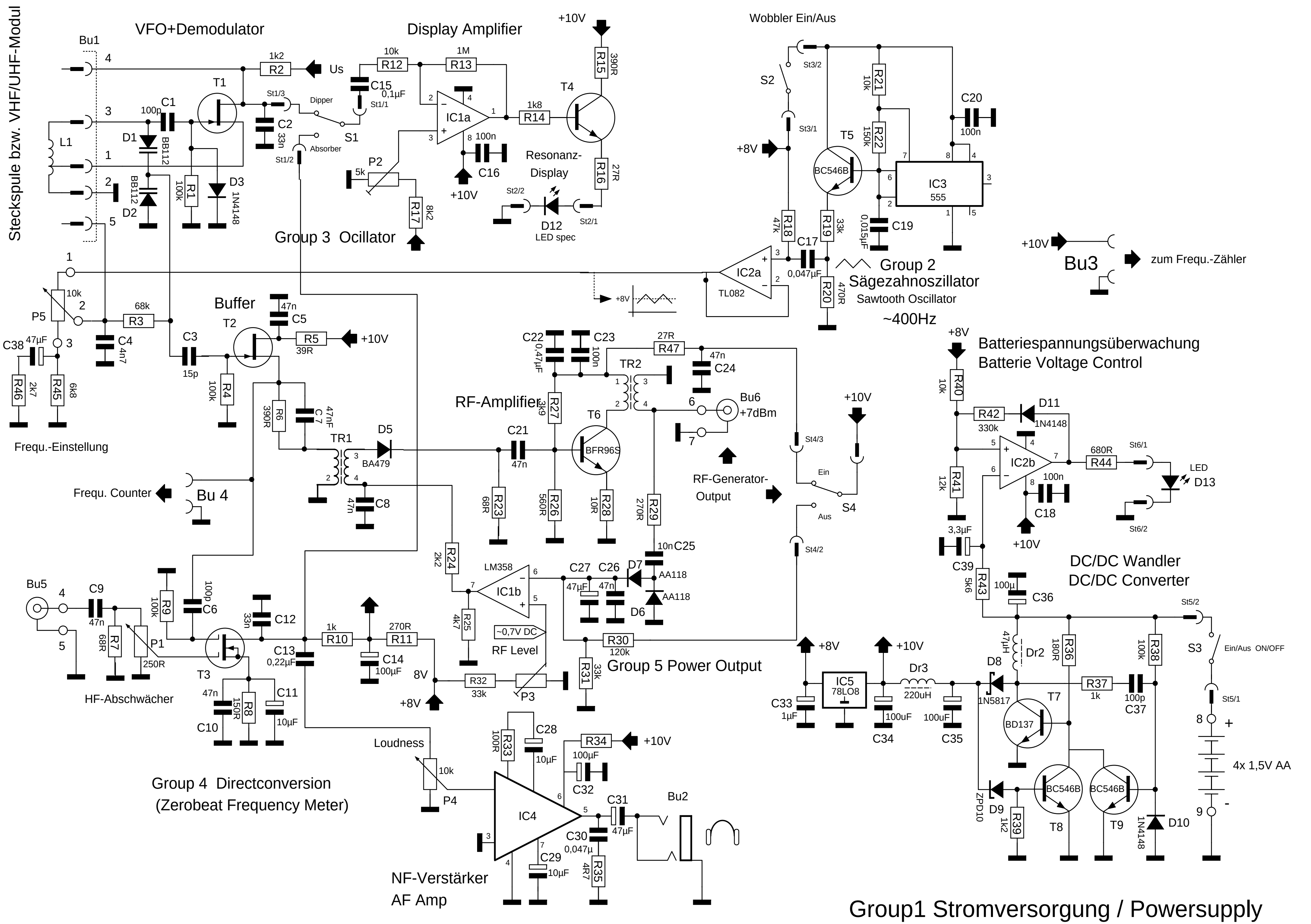
Total total: 62 Wdg 0,3mm CuL, tap with 12. Turn of the cold end.
People have asked us why we do not us a coil with ferrite core, which would lower the number of turns dramatically. The answer: we wanted to build here a high-quality measuring instrument useful to us. A coil with ferrite core would bundle the lines of flux strongly inside the coil and is exactly that an effect, which we can need with a Dipper in no case. With an air core the lines of flux spread unrestrainedly outward, which makes it substantially more sensitive and thus make unloaded measurements possible. Always remember: the more strongly the item under test is loaded, all the more strongly it changes its resonant frequency, all the more wrongly is our result of measurement.

Reel 5:1,25 MHz-2,56MHz

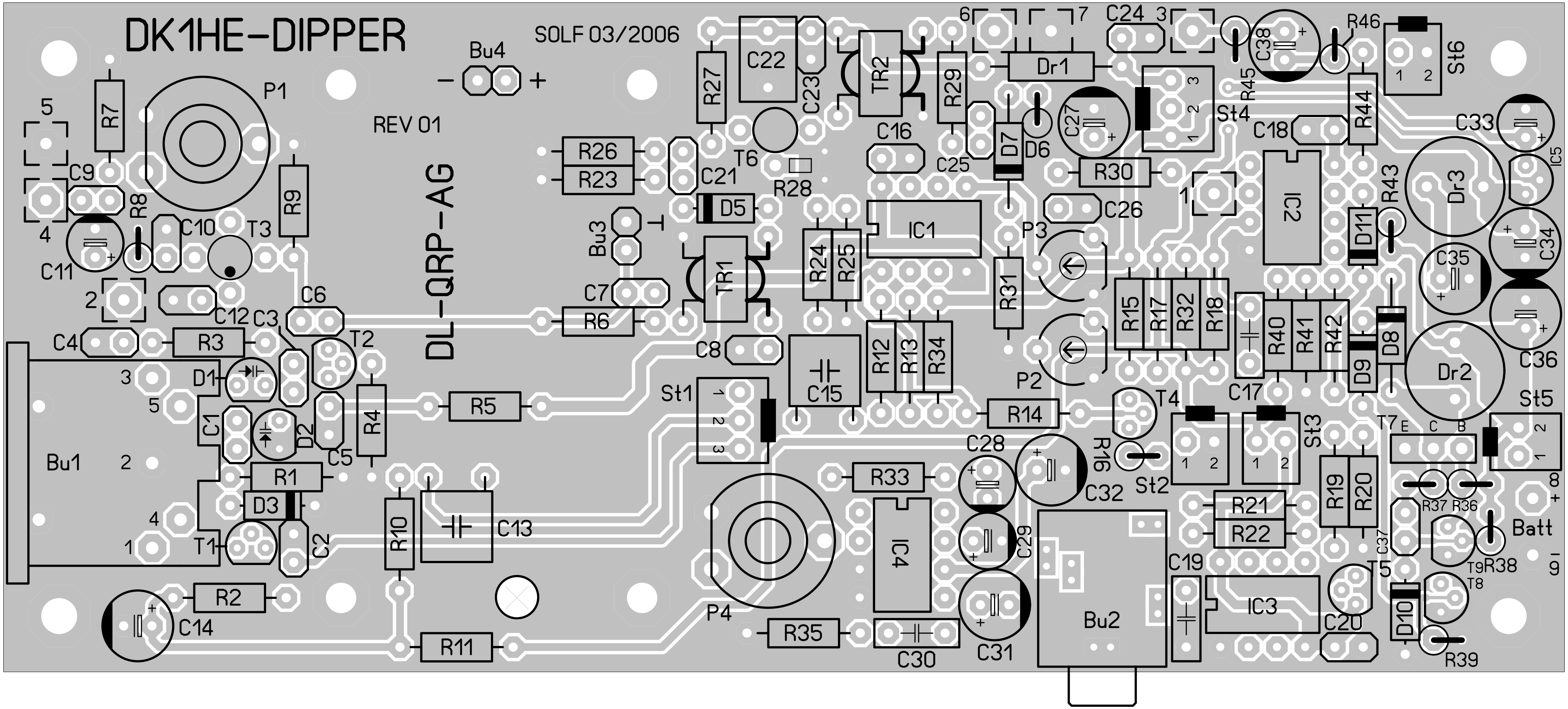
Lges= 35mm/A1= 2mm/A2= 11mm

Total total: 95 Wdg 0,1mm CuL, tap with 19.

Turn of the cold end Who would like itself to manufacture a coil for the old ZF 455 kHz, accordingly many turns on a further spool winding must. Remember, no ferrite use. The coil may be wound also 2-lagig.

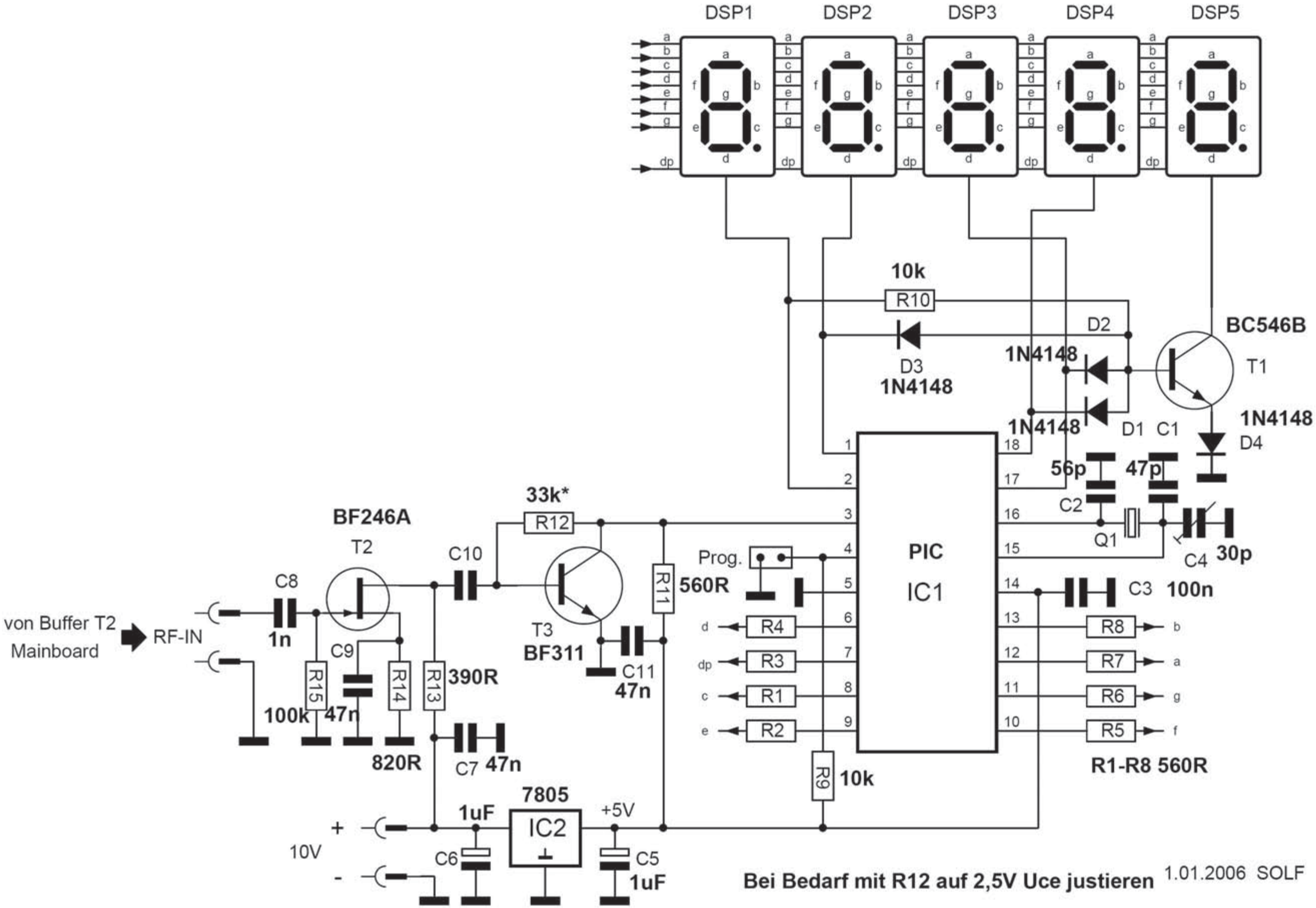


November 22.2007

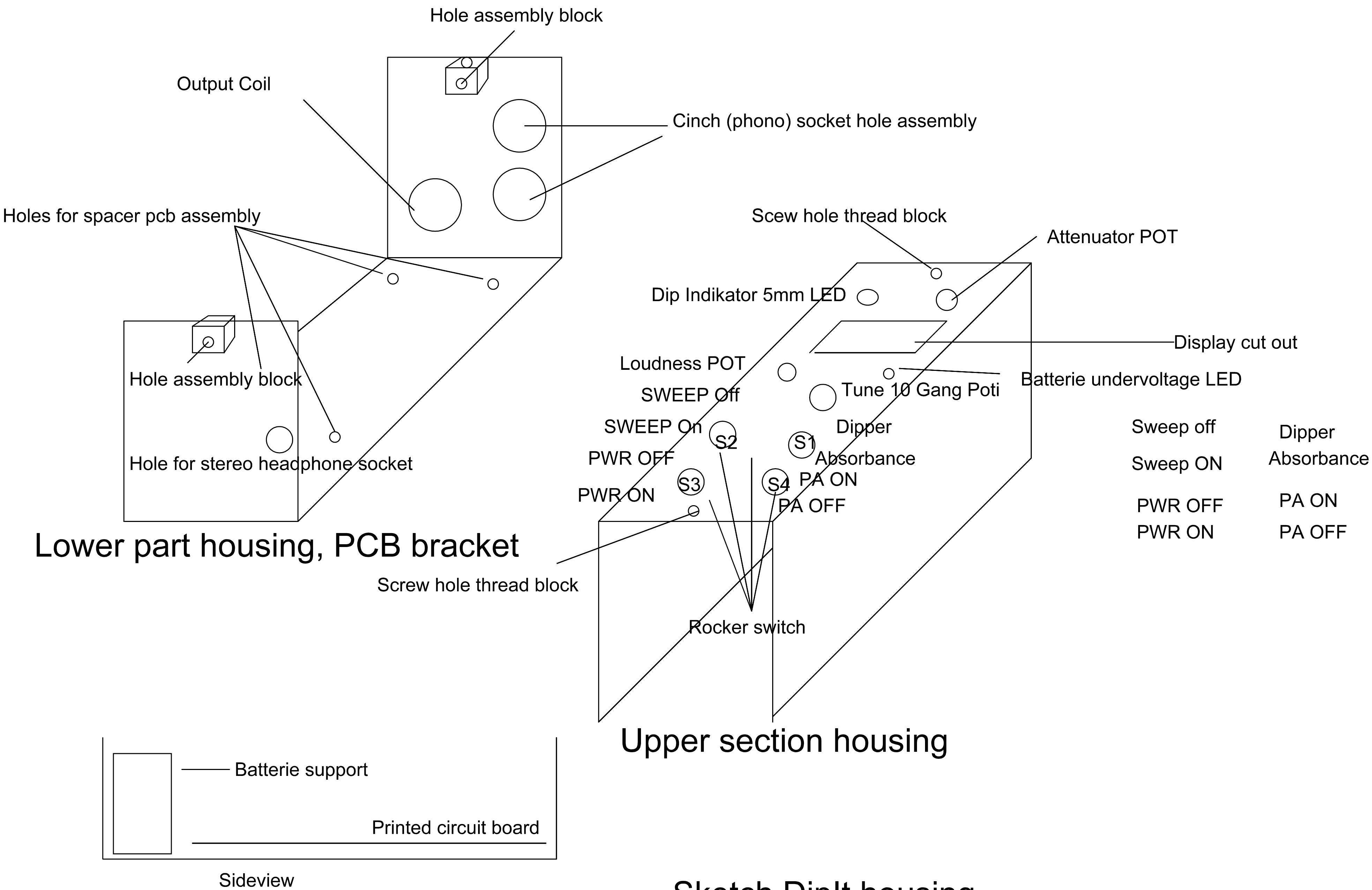


November 22.2007

DL4YHF-Counter



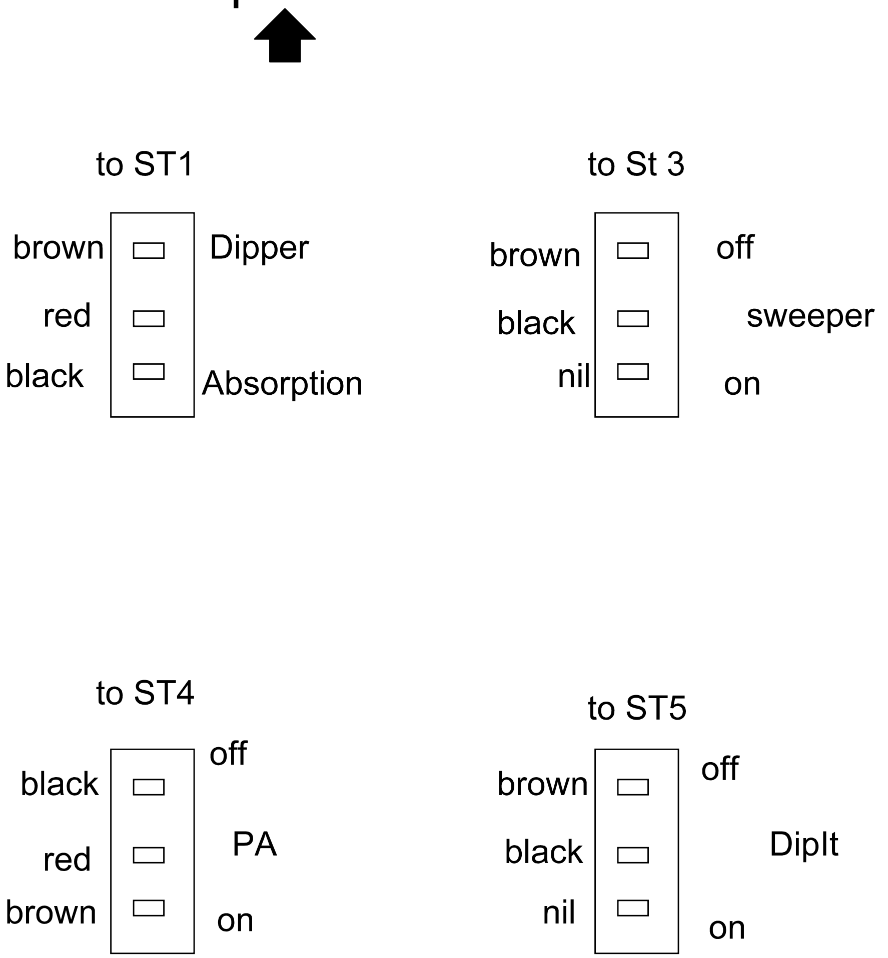
November 22.2007



Sketch DipIt housing

November 22.2007

Dipit Coil



Switches seen from solder side

Shorten the cables and solder the colours as shown in the drawing

Attention: switches are sensitive against too much heat

At the battery support attach the ground to screw. For the sake of insulating use tape or a piece of pasteboard(cardboard), it could otherwise Short-circuit with the housing, the same is also recommended with the jack headset-phone and the screw in the thread block against the battery. Because of the housing tolerances the thread block presses the edge on the battery it's recommended the thread block edge be pushed diagonally

Install the first the circuit borad into the housing. Use for it the 5mm spacer. The battery support comes into the housing bowl at the lower end of the circuit board. Connect the red wire of the tie-clip with pin 8 and the black wire of the tie-clip with pin 9 of the circuit board (take in addition ever one of the provided Steckschuhe)

Connect a 1xUM switch with the help of to three-wire cables/plug combination with St1. The switch is S1, it switches between Dipper/absorber

Connect a 1xUM switch with the help of to two-wire cables/plug combination with St3. The switch is S2, for the Oscillator.
Connect a 1xUM switch with the help of to two-wire cables/plug combination with ST5. The switch is S3, the battery main switch. Connect a 1xUM switch with the help of to three-wire cables/plug combination with St4. The switch is S4, circuit breakers for the +7dBm amplifier.
Connect the 10-turn potentiometer with the pin 1,2,3. Use the lugs. Build the jack headset-phone into the foot of the bottom case (beside the battery pack)
Connect the 5mm LED with the help of a 2-wire cable/plug combination with St2. The cathode (short leg) goes on ST2/2, that is the ground side. Use the plastic LED grommett for mounting the assembly in the case. Connect the 3mm LED with the help of two wires with the circuit board drillings at the position St 6. St6 may not be installed, since otherwise the switch fits above and the housing cannot not be closed. The short leg (cathode) comes into the drilling St6/2 (ground side) A Cinch (phono) socket screws into the front wall of the lower shell and connects the interior pin with pin 4 and the ground connection with pin 5. This phono socket is the input to the overlapping frequency meter. The second Cinch socket screws into the front wall and connects the interior pole with pin 6 and the ground side with pin 7. This Cinch(phono) socket is the output of the +7dBm of amplifier. The housing is bolted with the two pedestals. The ground side of the pedestal for the side with the battery support points to the batteries.
Calibration of the +7dBm of amplifier. The amplifier can be calibrated very exact by its inserted HF probe and the rule loop. Switch the Oscillator off. Terminate the HF output with 50 ohms. If you do not have QRP dummy load (e.g. the thermal wattmeter), then use a non-wirewound (carbon) 50 ohms resistor. Switch on the HF amplifier. DC voltage measures at IC 1 pin 7 and adjust it with the trimmer P3 to exactly xxx millivolts. At the output of the Dipmeter now a very exactly +7dBm lines up.
P2 in the display amplifiers building group. P2 is adjusted in such a way that the breakdown voltage of the diode without control is reached by the Dipper. In addition the coil is taken off and P2 adjusted in such a way that the LED just „visibly glows „. The same in position „Dipper „and „Oscillator"
Attitude of the counter: With a Dipper it does not depend on a few Hertz. One can adjust the indicated frequency by means of the trimmer C4 on the counter board in comparison to a reliable external frequency source.

If you already know how to use a Dipmeter, then you can now proceed. If not, then look at the provided QRPproject manual CD (unfortunately it's in German only). Under DipIt you find a collection of articles Dipping and using a Dipper. Don't let it bother you to that all the literature is from the years 1965 to 1975, it also add a few newer things. Apart from the fact that Dipping was more heavily used in the past with older equipment (sensitivity frequency dial etc.) all the described methods directly transfer to uses today.

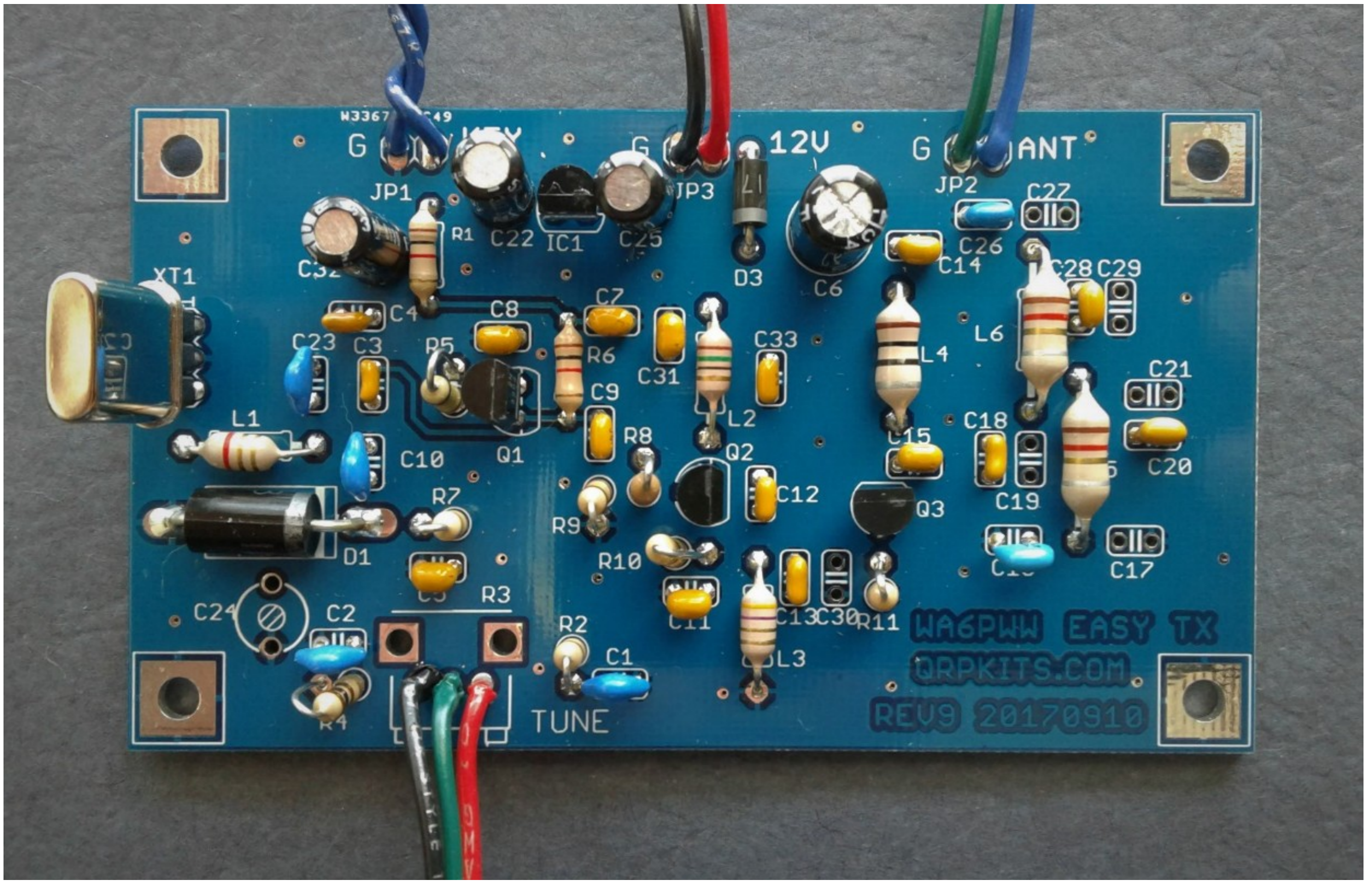
If you read all this and tried it out you will have fun with the DipIt and then can also say:

I Build the DipIt

We wish you much fun and Dipping

The QRPproject team

Pacific Antenna Easy Transmitter Kit



Introduction

The Easy Transmitter kit from qrpkits.com provides a crystal controlled transmitter with VXO tuning.

The circuit consists of a 2N3904 based crystal oscillator with VXO. The oscillator feeds a 2N3904 buffer/driver stage and the final amplifier stage utilizes a BS170.

Description

Provides approximately 2 to 2.5 watts when powered from a 9-14 volt supply.

5 pole low pass filter with elliptic capability to provide a clean signal.

Tuning range of approximately 1 kHz on 40M.

Crystal included for either 7.030 or 7.040 frequencies (choose at time of ordering).

Uses all molded inductors with no toroids or other coils to wind.

Easy to assemble- a great first kit for new or returning builders or as a club project.

Support

Email: qrpkits.com@gmail.com

Recommended Tools

- ◻ Temperature Controlled Soldering Station with small tip or 15-35 watt soldering iron with a small tip.
- ◻ Solder 60/40 or 63/37 Tin-Lead or leadfree
- ◻ Small Diagonal Cutters
- ◻ Small Needle Nose Pliers
- ◻ Pencil, Pen, and/or Highlighter
- ◻ BRIGHT work light

Optional

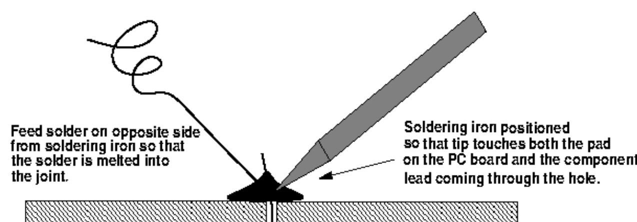
- ◻ Magnifying headpiece or lighted magnifying glass.
- ◻ Multi-meter
- ◻ Dummy Load
- ◻ Scope or RF power meter
- ◻ Solder Sucker or Solder Wick
- ◻ Small multi-blade Screw Driver
- ◻ Knife or Wire Stripper
- ◻ Small Ruler
- ◻ Cookie Sheet to build in and keep parts from jumping onto the floor.

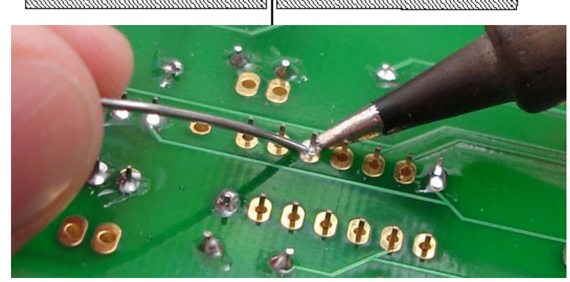
Construction Techniques

- ◻ The Parts List has columns for inventory and construction.
- ◻ Please take time to inventory the parts before starting. Report any shortages to QRPKITS.com (In many cases it may be faster and cheaper to pull a replacement from your parts supply, but please let us know if we missed something.)
- ◻ Pre-sorting the resistors and capacitors can speed up the assembly and reduce mistakes.
- ◻ **There is no need to print out the whole assembly manual unless you want a copy. Print the Parts List and Schematic (last two pages) then view the rest of the manual on a computer, laptop, or tablet.**
- ◻ You can insert several parts at a time onto the board. When you insert a part bend the leads over slightly to hold the part in place, then solder all at the same time. Clip the leads flush.
- ◻ Most parts should be mounted as close to the board as possible. Transistors should be mounted about 1/8" above the board. Solder one lead on ICs or IC sockets and then check to make sure the component is flush before soldering the remaining leads.

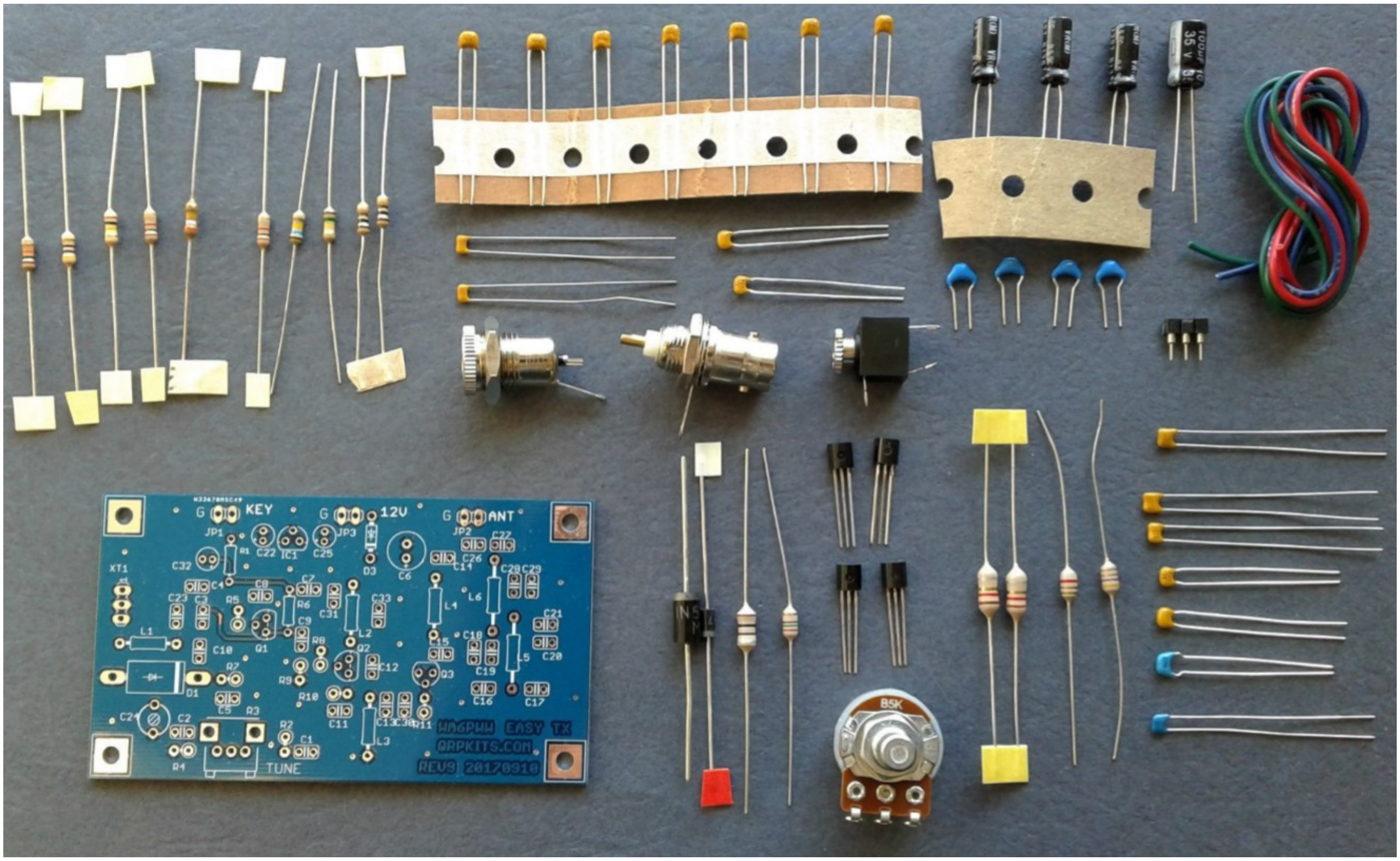
Soldering Technique

- ◻ Use a Temperature Controlled Soldering Station with small tip or 15-35 watt soldering iron with small tip. Conical or very small screw driver tips are best.
- ◻ DO NOT use a large soldering iron or soldering gun.
- ◻ If you are a beginner, new to soldering, there are a number of resources on the web to help you get on the right track soldering like a pro. Google "Soldering Techniques".

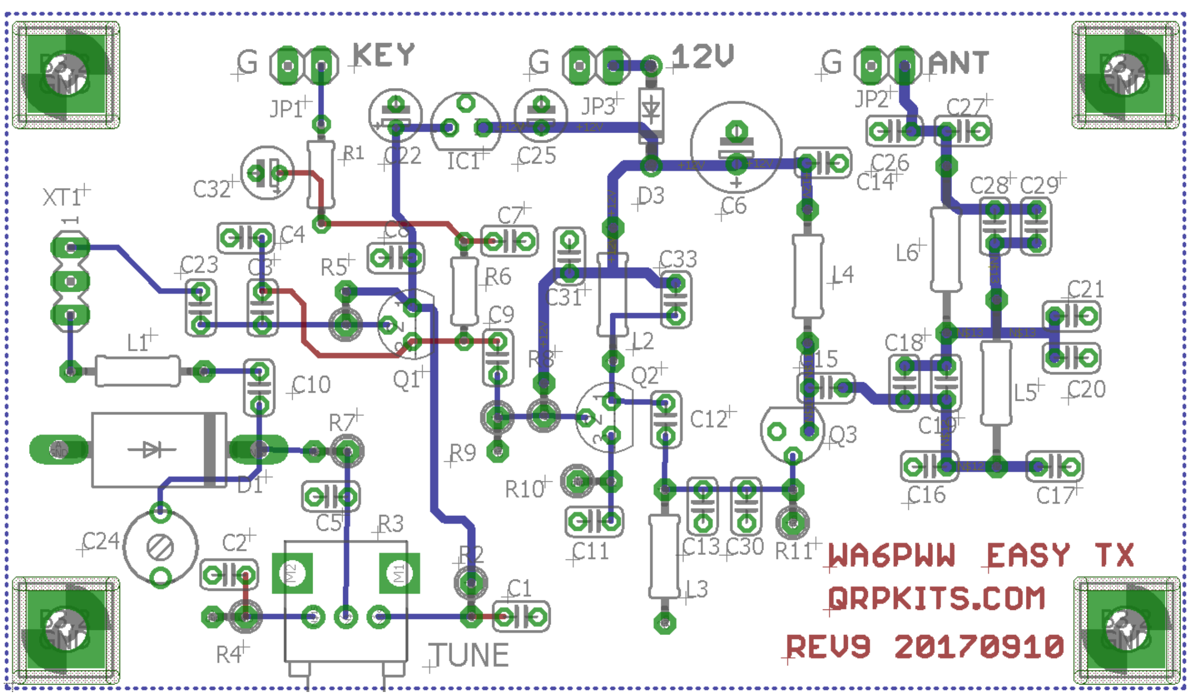




Typical Parts Included in the Kit



Board Layout



Inventory and Parts List

Use the last columns to inventory the kit parts and to check off as they are installed.

Qty	Value	Description	Parts	Identification	Inv	Inst.
1	47 ohm	RESISTOR, 1/4W	R10	Yel-vio-blk-gold		
2	100 ohm	RESISTOR, 1/4W	R2, R4	Brn-blk-brn-gold		
2	1K ohm	RESISTOR, 1/4W	R1, R6	Brn-blk-red-gold		
1	10K ohm	RESISTOR, 1/4W	R11	Brn-blk-org-gold		
1	100K ohm	RESISTOR, 1/4W	R7	Brn-blk-yel-gold		
1	150K ohm	RESISTOR, 1/4W	R9	Brn-grn-yel-gold		
1	160K ohm	RESISTOR, 1/4W	R5	Brn-blu-yel-gold		
1	390K ohm	RESISTOR, 1/4W	R8	Org-wht-yel-gold		
2	22pF	CAPACITOR, mono	C9, C12	Marked 22 or 220		
2	68pF	CAPACITOR, mono	C3, C4	Marked 68 or 680		
4	1000pF	CAPACITOR, mono	C1, C2, C10, C23	Marked 102		
7	0.1uF	CAPACITOR, mono	C5, C7, C8, C11, C14, C15, C31	Marked 104		
1	1 uF	Elect. Capacitor	C32	Marked 1 uF		
2	4.7uF	Elect. Capacitor	C22, C25	Marked 4.7uF		
1	100uF	Elect. Capacitor	C6	Marked 100uF		
1	10uH	INDUCTOR molded	L4	Brn-Blk-Blk-Slv or Gld		
1	15uH	INDUCTOR molded	L2	Brn-Grn-Blk-Slv or Gld		
1	1N5408	DIODE	D1	Large, marked 1N5408		
1	1N5817	1.0A RECTIFIER	D3	Small, marked 1N5817		
2	2N3904	NPN Transistor	Q1, Q2	TO92, Marked 2N3904		
1	BS170	MOSFET	Q3	TO92, Marked BS-170		
1	78L09	V Regulator	IC1	TO92, Marked LM78L09		
1	BNC	Panel BNC	Panel BNC	BNC panel mount		
1	Jack	3.5mm mono jack	3.5mm audio jack	Black 3.5mm mono jack		
1	Jack	2.1mm power jack	Coaxial Power Jack	Metal or plastic power jack		
1	5K	R3, Potentiometer	Potentiometer, panel B5K	B5K linear potentiometer		
1	Knob	Small knob	Knob	Small black knob		
1	Header	3 pin round pin strip	XT1	crystal socket		
1	Wire	Hookup wire 3 colors	Hookup wire, 3 colors, 8" each	Hookup wire, 3 colors		
1	PCB	Circuit Board	ETX Rev9	PCB ETX Rev9		
1	47pF	CAPACITOR, mono	C13 40M BANDKIT	Marked 47 or 470		
	*	CAPACITOR, mono	C30 BANDKIT	Not used		
1	22pF	CAPACITOR, mono	C33 40M BANDKIT	Marked 22 or 220		
1	360pF	CAPACITOR, mono	C16 40M BANDKIT	Marked 361		
	*	CAPACITOR, mono	C17 BANDKIT	Not used		
1	47pF	CAPACITOR, mono	C18 40M BANDKIT	Marked 47 or 470		
	*	CAPACITOR, mono	C19 BANDKIT	Not used		
1	680pF	CAPACITOR, mono	C20 40M BANDKIT	Marked 681		
	*	CAPACITOR, mono	C21 BANDKIT	Not used		
1	330pF	CAPACITOR, mono	C26 40M BANDKIT	Marked 331		
	*	CAPACITOR, mono	C27 BANDKIT	Not used		
1	100pF	CAPACITOR, mono	C28 40M BANDKIT	Marked 101		
	*	CAPACITOR, mono	C29 BANDKIT	Not used		
2	1.2uH	INDUCTOR molded	L5, L6 40M BANDKIT	Brn-Red-Gld-Slv or Gld		
1	4.7uH	INDUCTOR molded	L3 40M BANDKIT	Yel-Vio-Gld-Gld or Slv		
1	8.2uH	INDUCTOR molded	L1 40M BANDKIT	Gry-Red-Gld-Gld or Slv		
1	Crystal	7.030 OR 7.040	CRYSTAL, choice, Bandkit	Frequency marked		

Inserting the Parts

Note: A board layout showing parts locations and schematic diagram are located at the end of this manual, we suggest you print out a copy for reference during assembly.

Resistors

It is recommended to sort the resistors R1 through R11 by value and insert them smallest value first, largest value last.

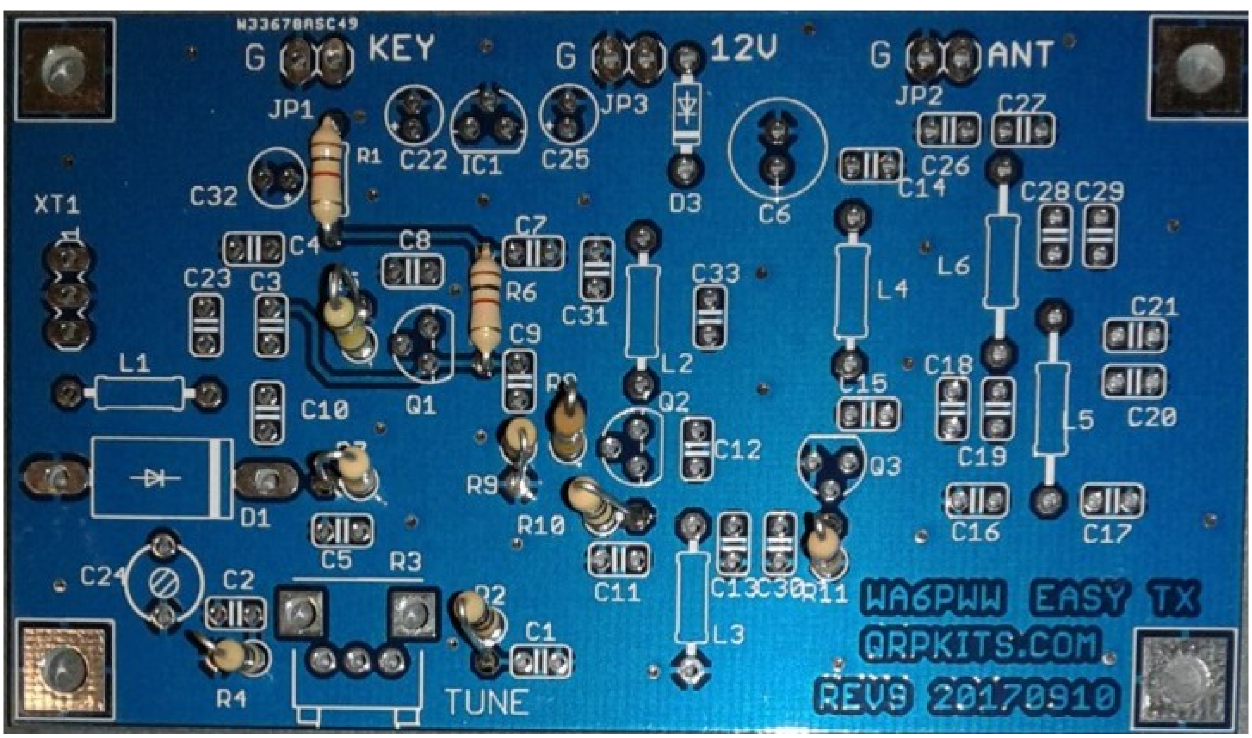
Be sure to check the color code for each resistor as you install. Confirming the value with an Ohm meter is always a good idea

A good reference for reading resistors is here:
http://www.token.com.tw/resistor/resistor-color-code.htm

Except for R1 and R6, the resistors are mounted standing up on the board. To do this, just bend one lead back along the resistor body before inserting into the board. This will leave the lead on top exposed that can serve as a test point for checking voltages for debugging.

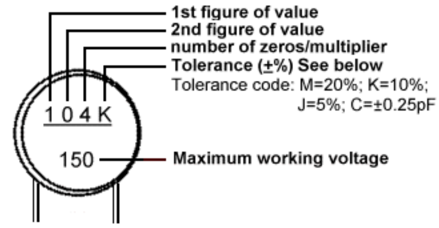
A good reference for mounting resistors vertically is here:
http://www.wb5rvz.com/sdr/common/Common_Component_Mounting.htm#resistors

See the photo below as a guide for resistor installation and locations



Ceramic Capacitors

Next sort by value and insert the capacitors C1 to C5 and C7 to C12 along with C14, C15, C23, C24 and C31.



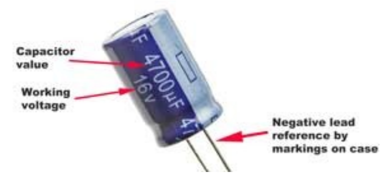
The molded ceramic capacitors will be somewhat rectangular and may be blue, tan or brown in color and will have the value marked on the body. It may require a good magnifier to read accurately.

Be sure to double check the values before soldering.

Note: Other capacitor positions are part of the bandkits and will be installed later. Not all capacitor locations are used so be sure to check installation guide and parts list for locations.

Electrolytic Capacitors

Now locate and insert the electrolytic capacitors C22, C25 (4.7uF), C32 (41uF) and C6 (100uF)

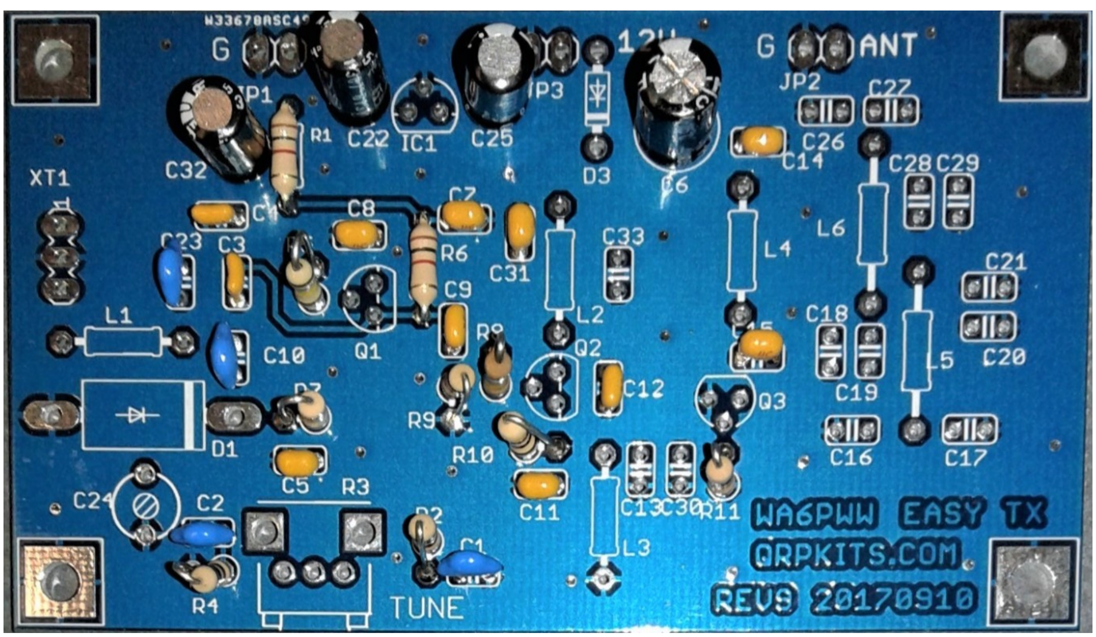


They are round cans with leads and are usually blue or black. The 1uF and 4.7uF capacitors are the same size and color and are easily confused so be sure to check labels and location. The 1uF is C32.

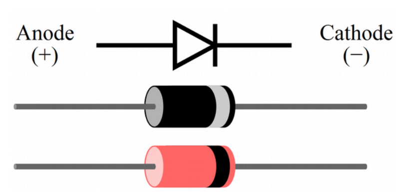
Note: that electrolytic capacitors are polarized and must be installed correctly.

The longer lead is usually the positive + (plus) lead and should go in the positive hole that is marked on the circuit board with a + symbol.

The shorter lead is usually the - (minus) lead. The negative lead is also marked with a black bar on the side of the capacitor so be sure to confirm with this marking before soldering.



Diodes



Sort and install the diodes D1 and D3. Be sure to confirm the value and double check orientation before soldering. Diode D1 (1N5408) is a large black plastic package and diode D3 (1N5817) is a medium sized black plastic case.

Inductors

Next, locate and install the inductors L2 and L4. They are similar in appearance to resistors but typically have larger bodies and slightly different shape than typical resistors.

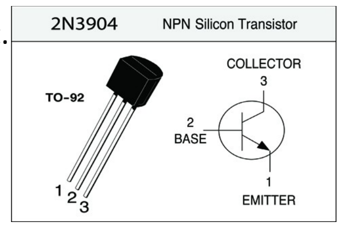
If in doubt, check with an ohmeter since inductors will have very low resistance as they are just coils of wire inside.

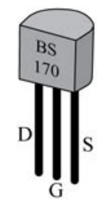
Bend the leads 90 degrees at the end and insert into the board positions as indicated.

Be sure to double check the color codes before soldering.

See the image below for typical appearance and location of the inductors.

Transistors and Voltage regulator





There are 3 transistors (Q1, Q2 and Q3) and one voltage regulator in the kit.

Q1 and Q2 are 2N3904 and Q3 is a BS-170.

The regulator (IC1) is a LM78L09.

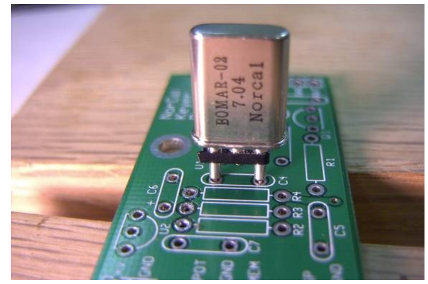
They are all in the same TO-92 package but can be identified by the markings on the flat side of the case.

You will need to slightly bend the center lead to fit the board layout.

Be sure to confirm the part and location before soldering.

See the image below for typical appearance and location of the transistors and the regulator (IC1)

Crystal Socket and Crystal



Install the 3 pin header to serve as a crystal socket that will hold the crystal.

We have a reference on the website to show how a socket can be made from a header strip: http://www.qrpkits.com/buildertip03.html

On the ETX kit, the board has a center hole so there is no need to trim the middle lead on the header strip, just solder the 3 pin strip in place

Bandkit Parts

It is now time to install the band specific parts.

These parts determine the frequency of operation of the transmitter and provide a low pass filter to reduce transmitted harmonic energy.

These parts are also listed and the main parts table and relisted here as an aid to building

Qty	Value	Description	Parts	Identification	Inv	Inst.
1	47pF	CAPACITOR, mono	C13 40M BANDKIT	Marked 47 or 470		
	*	CAPACITOR, mono	C30 BANDKIT	Not used		
1	22pF	CAPACITOR, mono	C33 40M BANDKIT	Marked 22 or 220		
1	360pF	CAPACITOR, mono	C16 40M BANDKIT	Marked 361		
	*	CAPACITOR, mono	C17 BANDKIT	Not used		
1	47pF	CAPACITOR, mono	C18 40M BANDKIT	Marked 47 or 470		
	*	CAPACITOR, mono	C19 BANDKIT	Not used		
1	680pF	CAPACITOR, mono	C20 40M BANDKIT	Marked 681		
	*	CAPACITOR, mono	C21 BANDKIT	Not used		
1	330pF	CAPACITOR, mono	C26 40M BANDKIT	Marked 331		
	*	CAPACITOR, mono	C27 BANDKIT	Not used		
1	100pF	CAPACITOR, mono	C28 40M BANDKIT	Marked 101		
	*	CAPACITOR, mono	C29 BANDKIT	Not used		
2	1.2uH	INDUCTOR molded	L5, L6 40M BANDKIT	Brn-Red-Gld-Slv or Gld		
1	4.7uH	INDUCTOR molded	L3 40M BANDKIT	Yel-Vio-Gld-Gld or Slv		
1	8.2uH	INDUCTOR molded	L1 40M BANDKIT	Gry-Red-Gld-Gld or Slv		
1	Crystal	7.030 OR 7.040	CRYSTAL, choice, Bandkit	Frequency marked		

Bandkit Capacitors

Next sort by value and insert the bandkit capacitors listed above in the indicated locations.

Be sure to double check the value and location before soldering.

Note that all locations are not used.

Bandkit Inductors

Sort and install the bandkit inductors (L1, L3, L5, L6) in he indicated locations

Be sure to double check the value and location before soldering.

Completing your ETX Kit

Off board parts

Your Easy Transmitter board is now completed. For packaging and testing, you will find included in the package, a BNC, key connector, power connector and a tuning potentiometer along with some hookup wire.

You will need to provide DC power, a method for keying the transmitter and an antenna or dummy load for testing.

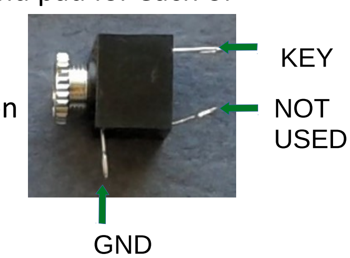
A method for measuring power output is also helpful for checkout.

Our Dummy Load Kit: http://qrpkits.com/dummyloadv2.html provides both a dummy load for the transmitter and an onboard RF probe for measuring RF power with only a multimeter.

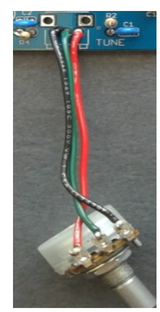
A fuse of 3-5 A rating is recommended in the power lead to protect in the event of a short. The transmitter is designed for power supplies in the 11-12V range but can be used with power supplies up to 15V.

The connections for Key, Antenna and Power input are labeled. G indicates the ground pad for each of these.

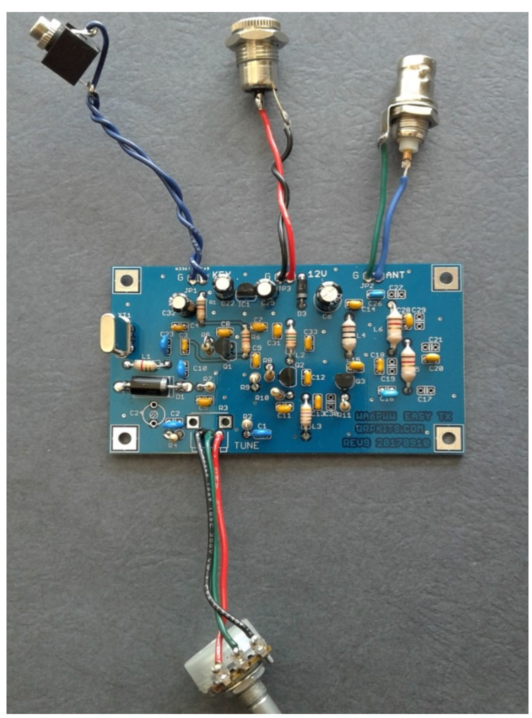
Note that the audio connector for a key only needs two connections. The third pin on the audio jack is for a switched connection and is not used.



The potentiometer is wired as shown in the photograph. The center pad on the board goes to the center connection of the potentiometer. In the orientation shown here, the outer wires cross over. This will result in tuning that goes up in frequency as the knob is turned clockwise. If the opposite occurs, just swap the outer leads on the potentiometer.



The photo below shows typical connections using the supplied parts.



Checkout

The Easy Transmitter is designed to be a simple to build and to use.

However, occasionally, problems may happen.

Problems are often soldering issues (shorts or cold solder joints) or component misplacement

Here are a few things to check if the kit does not function as it should.

1. Verify component placement, including resistors and capacitors

2. Inspect all solder joints with a magnifying glass, looking particularly for any that may have small whisker shorts or which look dull and blotchy indicating a cold solder joint.

3. Verify orientation of the diodes and transistors. One end of the diodes will have a marked band and this should match the board layout.

Packaging

Packaging is left up to the builder.

The ETX transmitter can be built into a case or operated open on the bench.

If used as an open board, use care not to damage or short connections on the bottom of the board

There are a number of suitable enclosures available online from companies such as Digikey, Mouser or from Ebay.

Operation

The Easy TX kit allows for limited tuning range around the crystal frequency. Turning the tuning dial will vary the operation from approximately 500Hz above the marked crystal frequency to 500Hz below.

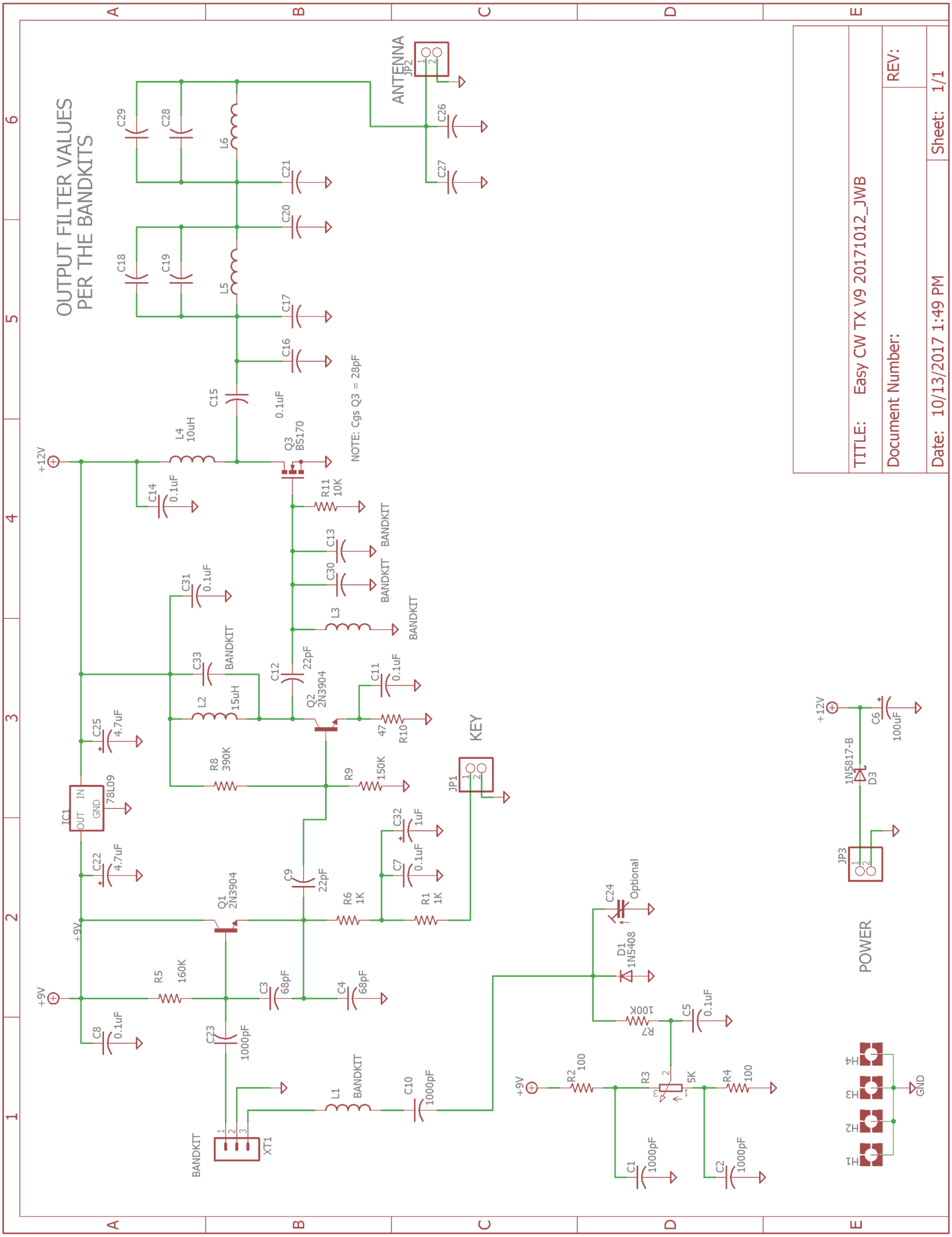
A point approximately in the middle of the tuning range will put the transmitter on the marked frequency but this may vary slightly from kit to kit.

The intent of the limited tuning is to provide sufficient range to put the transmitter on the chosen frequency without requiring excessive adjustment during operation.

Support

Email: qrpkits.com@gmail.com

Schematic Diagram



US 20150365013A1

(19) United States

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Hameed et al.

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(43) Pub. Date: Dec. 17, 2015

(54) RF-DC POWER CONVERTER

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(72) Inventors: **Zohaib Hameed**, Edmonton (CA); **Kambiz Moez**, Edmonton (CA)

(21) Appl. No.: **14/740,021**

(22) Filed: **Jun. 15, 2015**

Related U.S. Application Data

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Publication Classification

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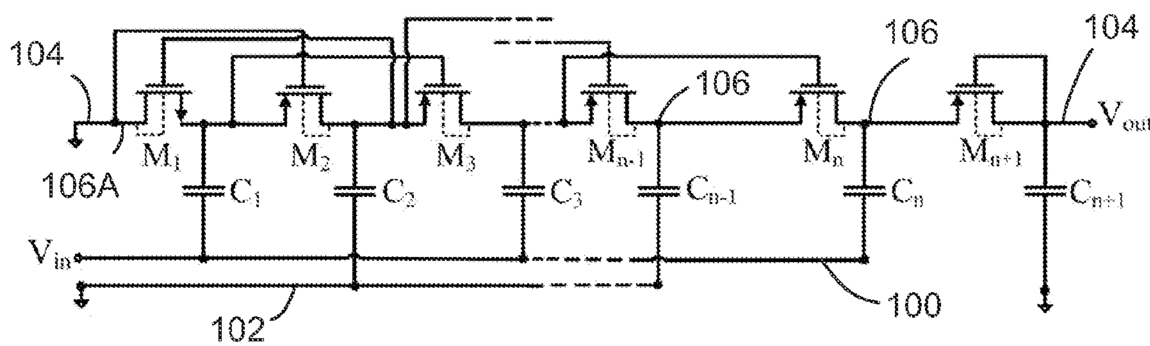
H02M 7/217 (2006.01)

(52) **U.S. Cl.**
CPC *H02M 7/217* (2013.01)

(57) ABSTRACT

A rectifier comprising a chain of transistors for RF-DC conversion. In order to compensate for the thresholds of the transistors, each transistor can be connected to a junction earlier or later in the chain. By using both p-type and n-type transistors in the same chain, the different types of transistors can be compensated in different directions allowing more transistors to be compensated. Additional transistors connected to the gates of transistors of the main chain can allow the transistors of the main chain to be forward compensated at one part of the input cycle and backward compensated in another part to minimize both the voltage threshold of the rectifier and the leakage current. The line for compensation of the voltage threshold during forward conduction can comprise a solid line or a transistor, and if a transistor is used it may be diode-connected.



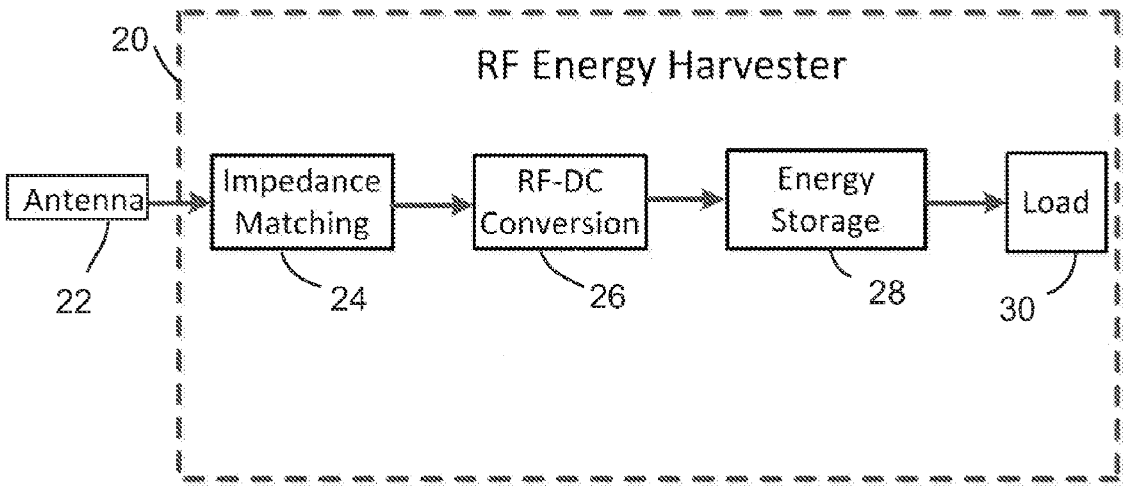


Fig. 1 (Prior Art)

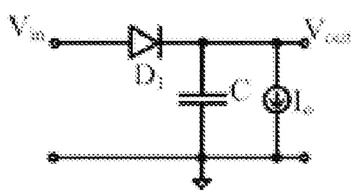


Fig. 2A (Prior Art)

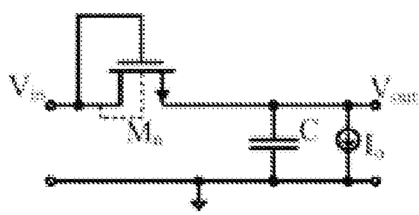


Fig. 2B (Prior Art)

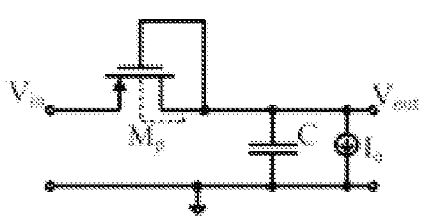


Fig. 2C (Prior Art)

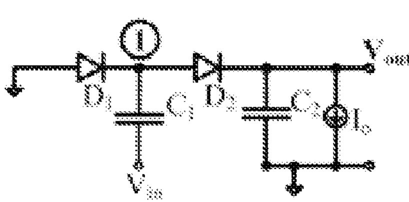


Fig. 2D (Prior Art)

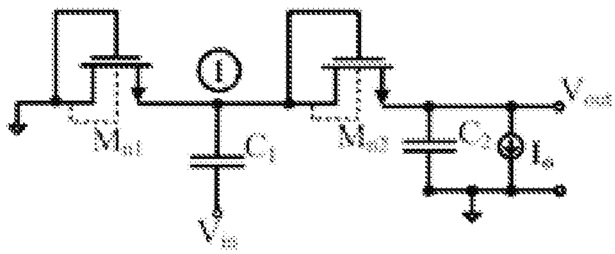


Fig. 2E (Prior Art)

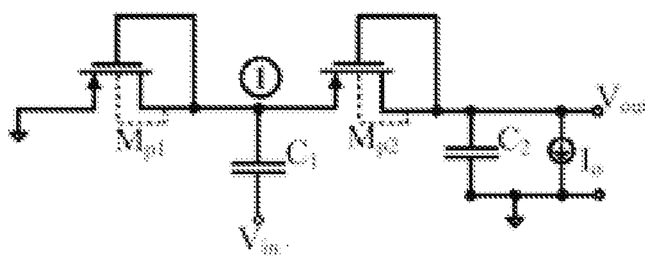


Fig. 2F (Prior Art)

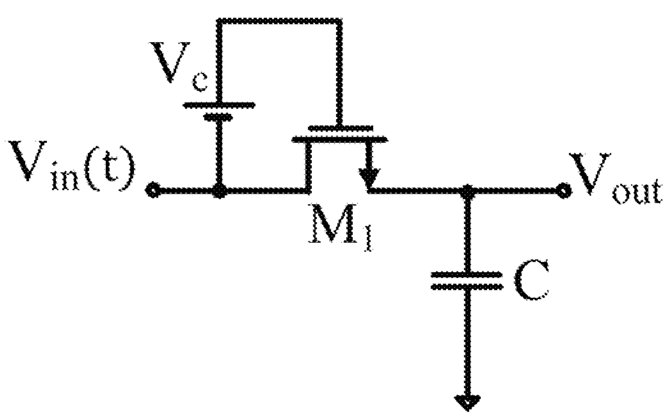


Fig. 2G (Prior Art)

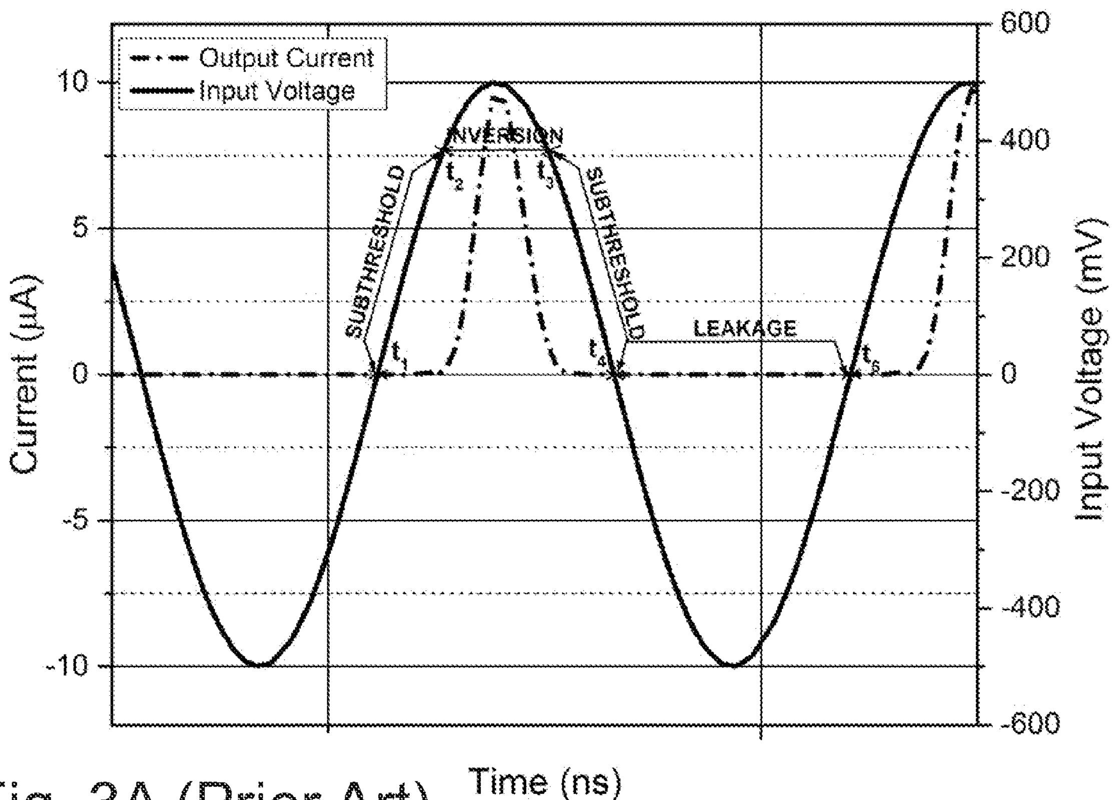


Fig. 3A (Prior Art)

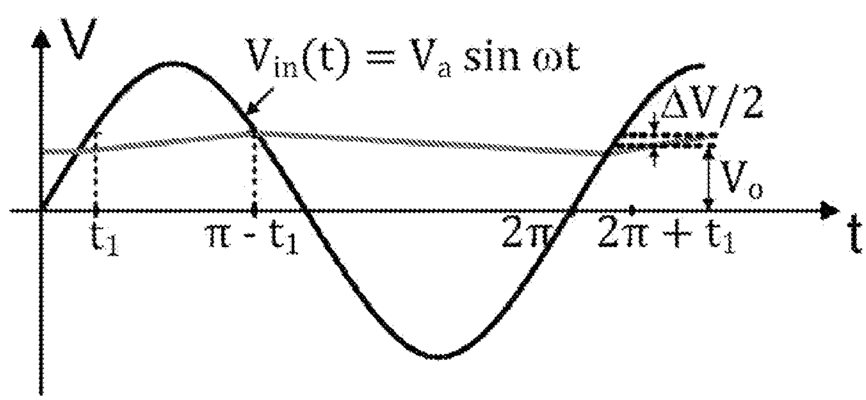


Fig. 3B (Prior Art)

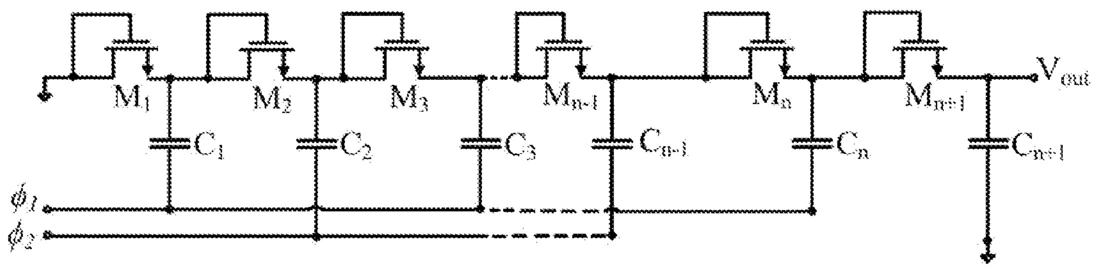


Fig. 4A (Prior Art)

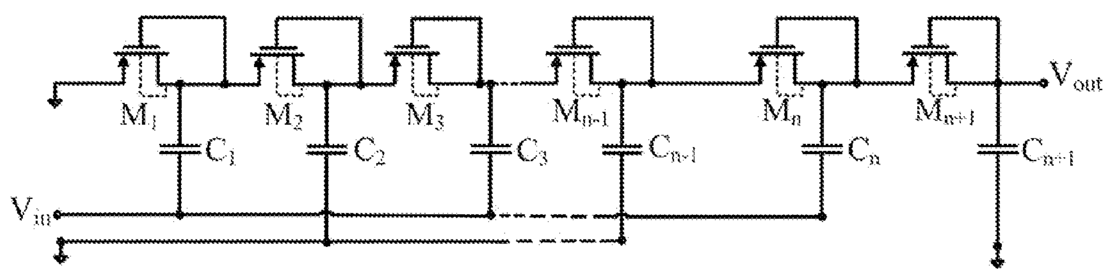


Fig. 4B (Prior Art)

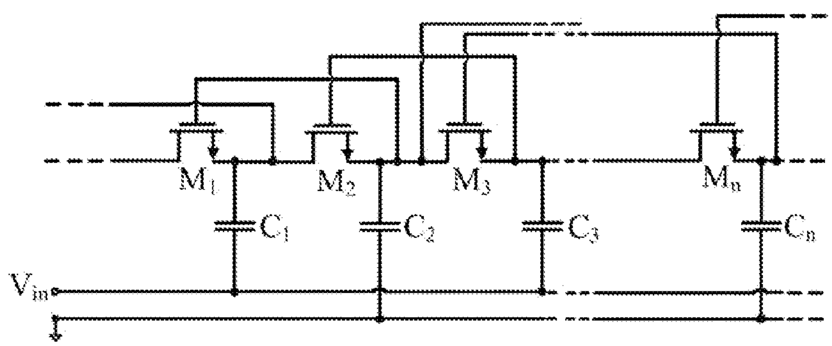


Fig. 5 (Prior Art)

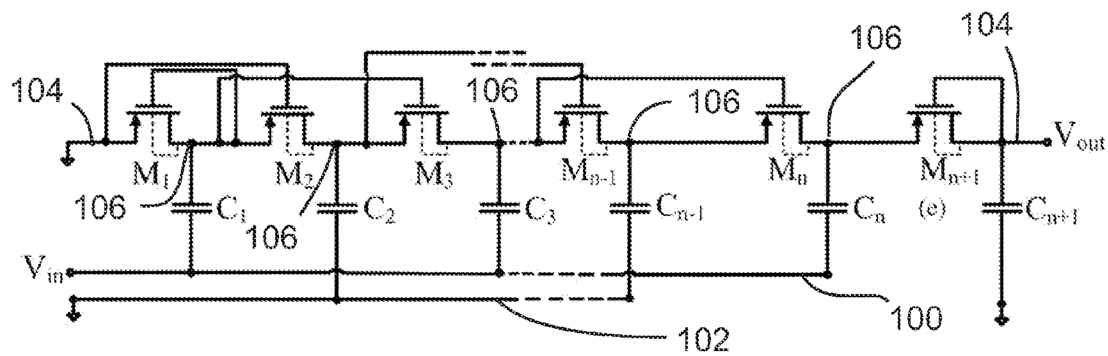


Fig. 6A

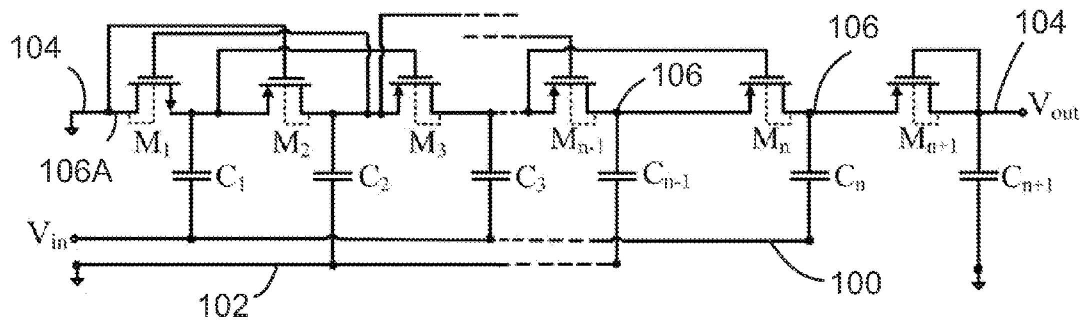

104
106A
M_1
M_2
M_3
M_{n-1}
106
M_n
106
M_{n+1}
104
V_{out}
C_1
C_2
C_3
C_{n-1}
C_n
C_{n+1}
V_{in}
102
100

Fig. 6B

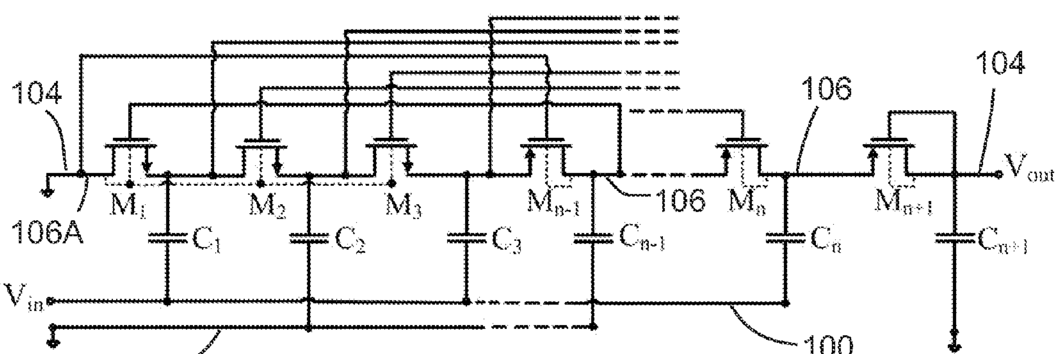
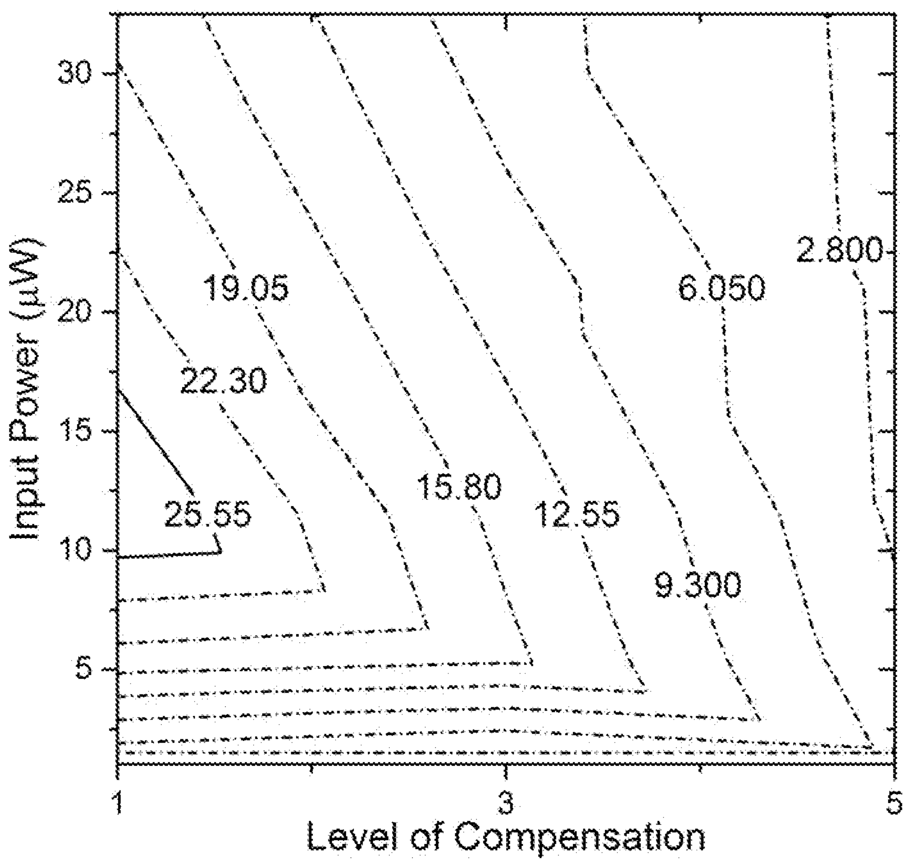

104
106A
M_1
M_2
M_3
M_{n-1}
106
M_n
106
M_{n+1}
104
V_{out}
C_1
C_2
C_3
C_{n-1}
C_n
C_{n+1}
V_{in}
102
100

Fig. 6C



Input Power (μW)
30
25
20
15
10
5
1
3
5
Level of Compensation
19.05
22.30
25.55
15.80
12.55
9.300
6.050
2.800

Fig. 7

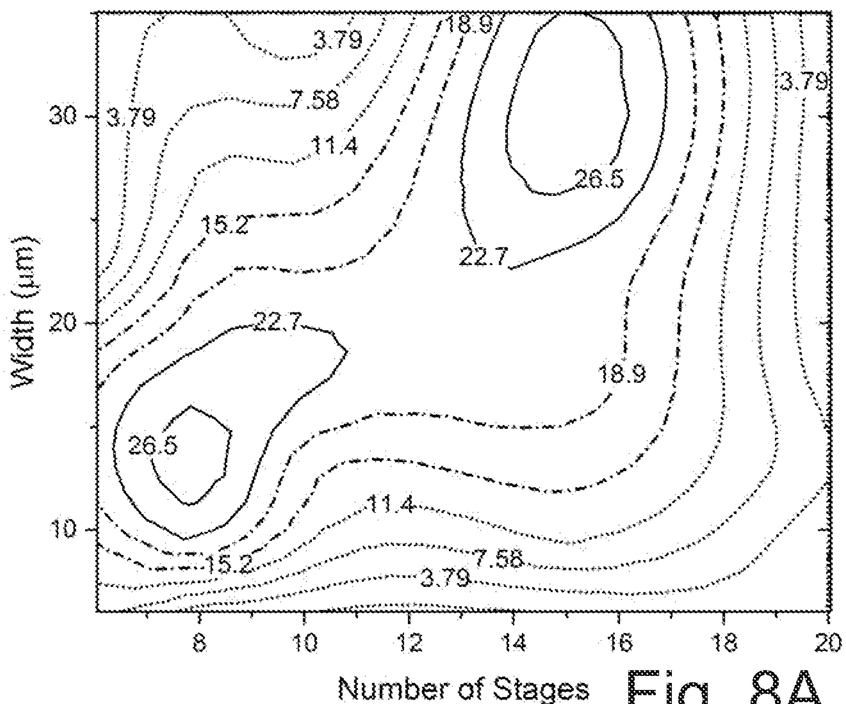

3.79
18.9
3.79
3.79
7.58
11.4
26.5
15.2
22.7
22.7
18.9
26.5
11.4
15.2
7.58
3.79
30
20
10
Width (μm)
8
10
12
14
16
18
20
Number of Stages

Fig. 8A

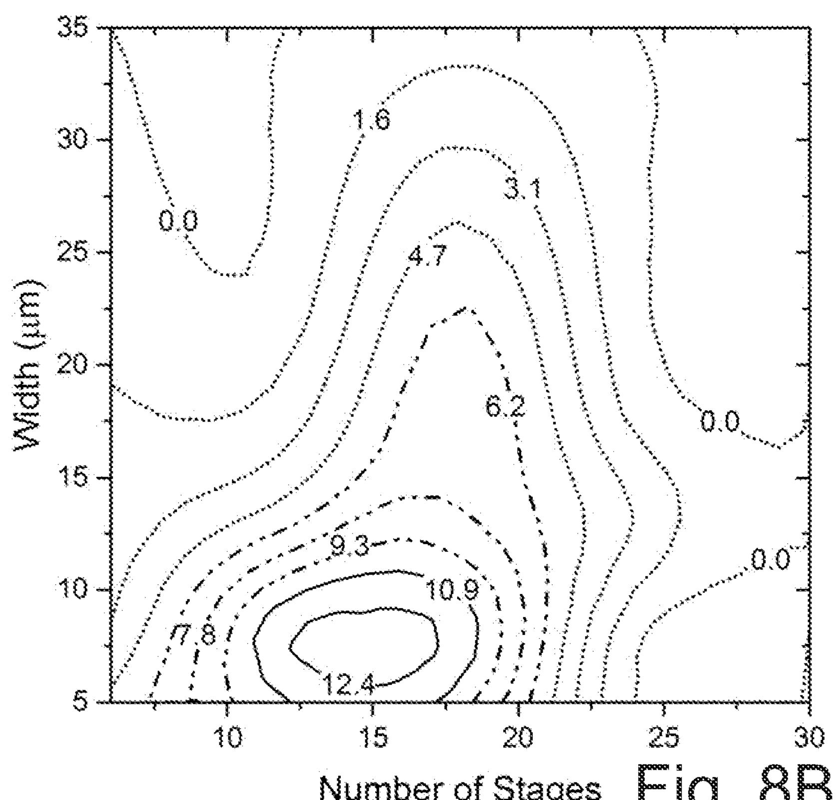
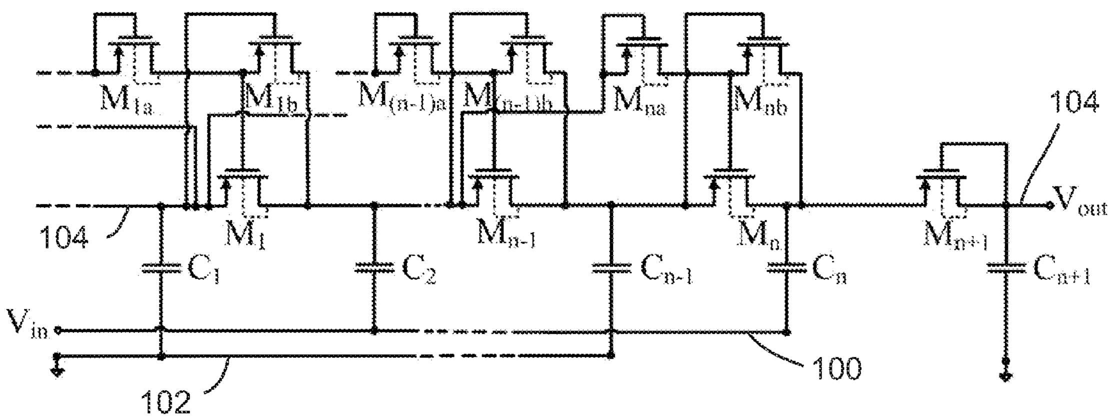
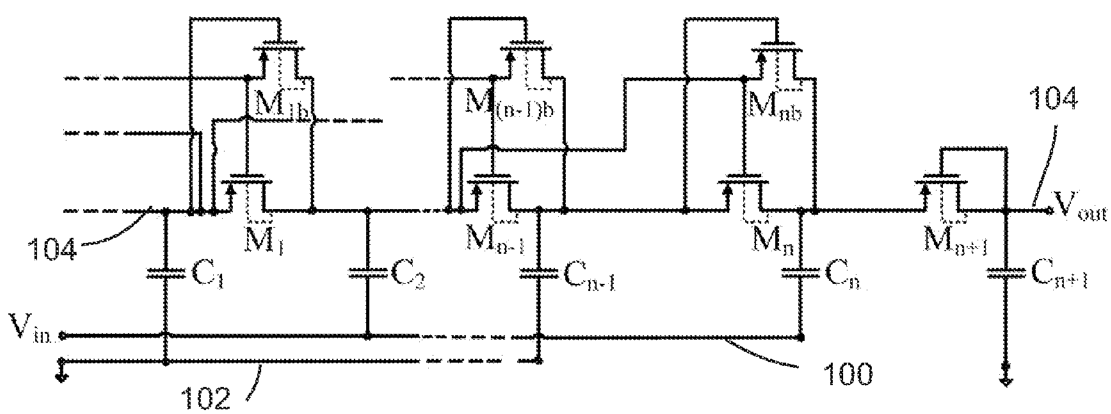

35
30
25
20
15
10
5
1.6
3.1
0.0
4.7
6.2
0.0
9.3
0.0
10.9
7.8
12.4
Width (μm)
10
15
20
25
30
Number of Stages

Fig. 8B



M_{1a}
M_{1b}
$M_{(n-1)a}$
$M_{(n-1)b}$
M_{na}
M_{nb}
104
V_{out}
104
M_1
M_{n-1}
M_n
M_{n+1}
C_1
C_2
C_{n-1}
C_n
C_{n+1}
V_{in}
100
102

Fig. 9A



M_{1b}
$M_{(n-1)b}$
M_{nb}
104
V_{out}
104
M_1
M_{n-1}
M_n
M_{n+1}
C_1
C_2
C_{n-1}
C_n
C_{n+1}
V_{in}
100
102

Fig. 9B

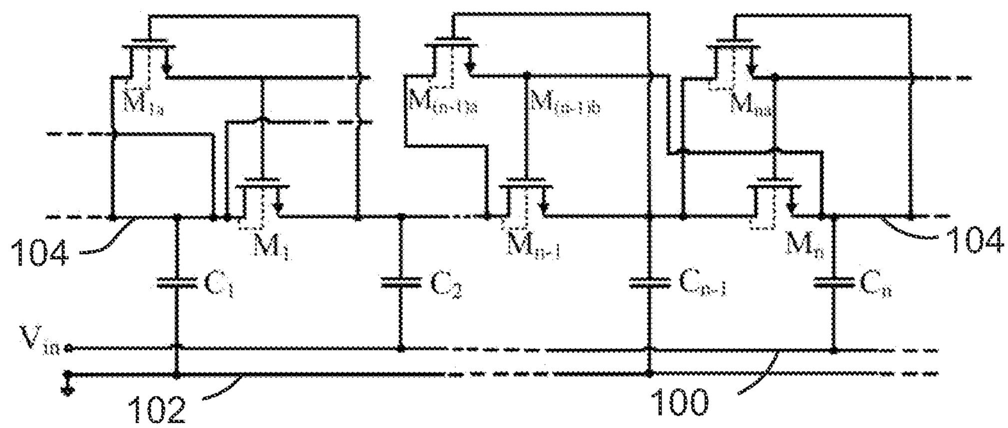

M1a
M(n-1)a
M(n-1)b
Mna
M1
Mn-1
Mn
104
104
C1
C2
Cn-1
Cn
Vin
102
100

Fig. 9C

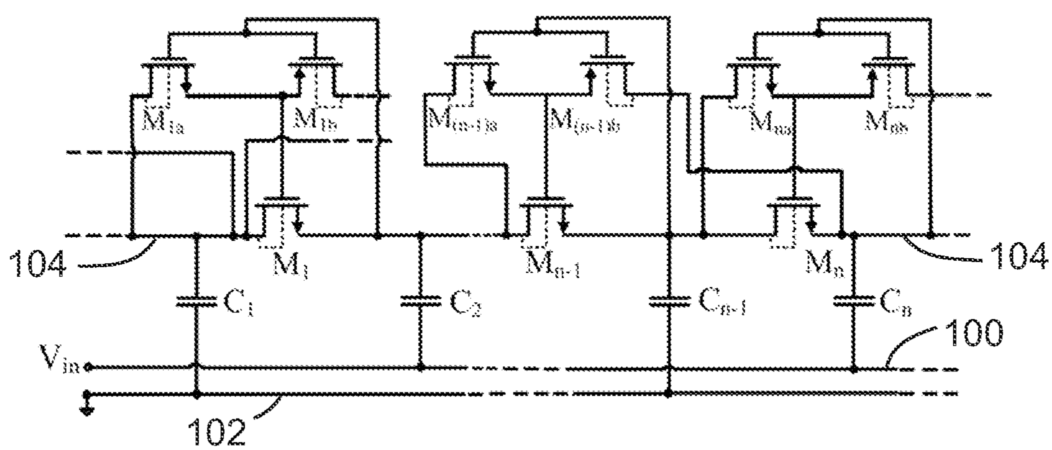

M1a
M1b
M(n-1)a
M(n-1)b
Mna
Mnb
M1
Mn-1
Mn
104
104
C1
C2
Cn-1
Cn
100
Vin
102

Fig. 9D

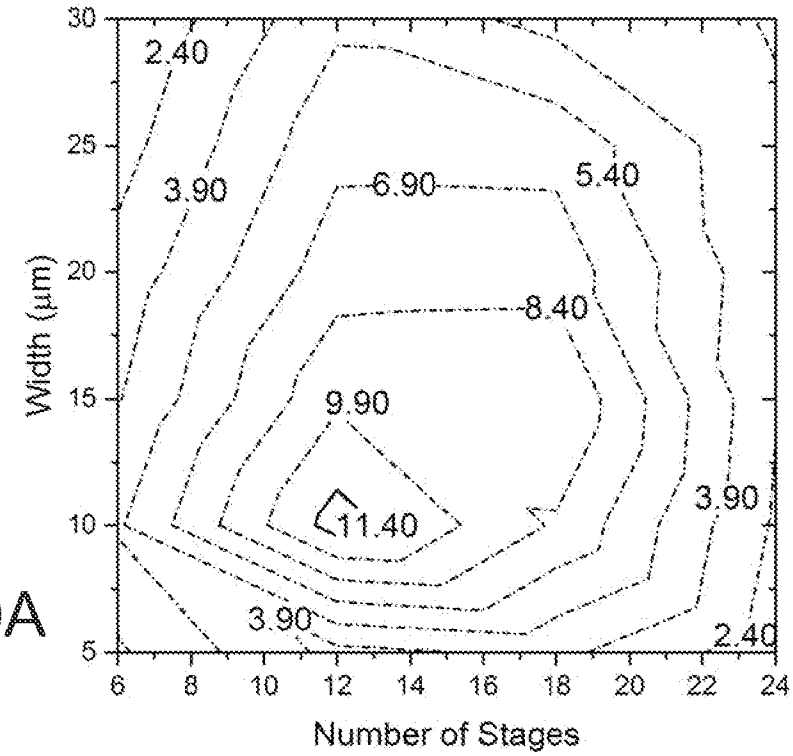


Fig. 10A

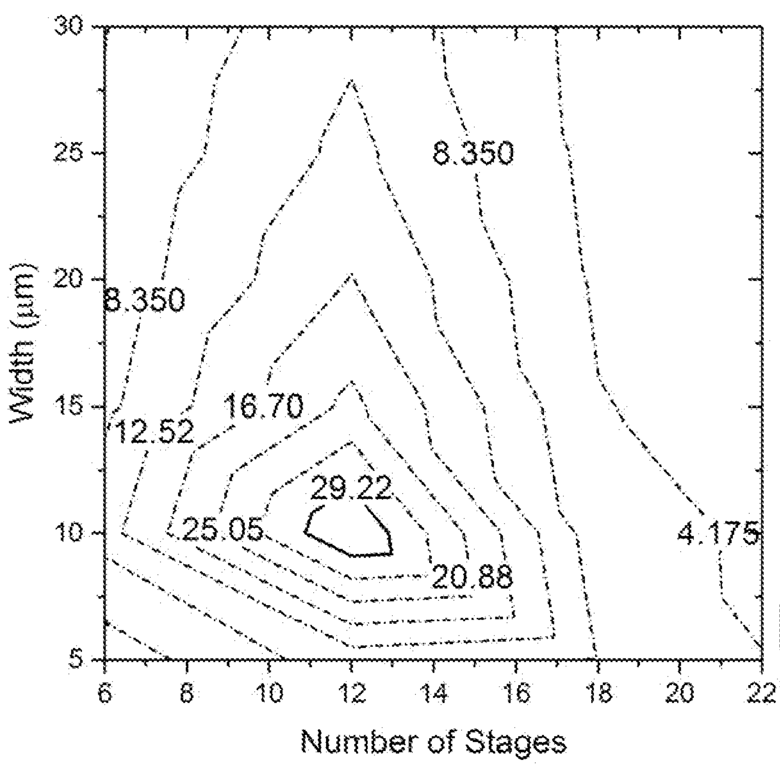


Fig. 10B

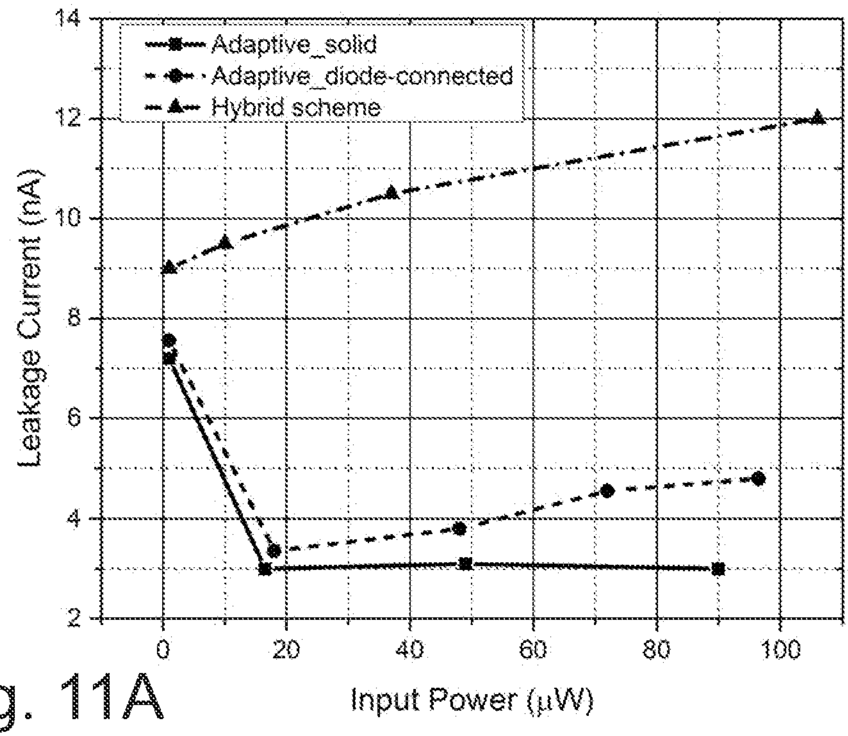


Fig. 11A

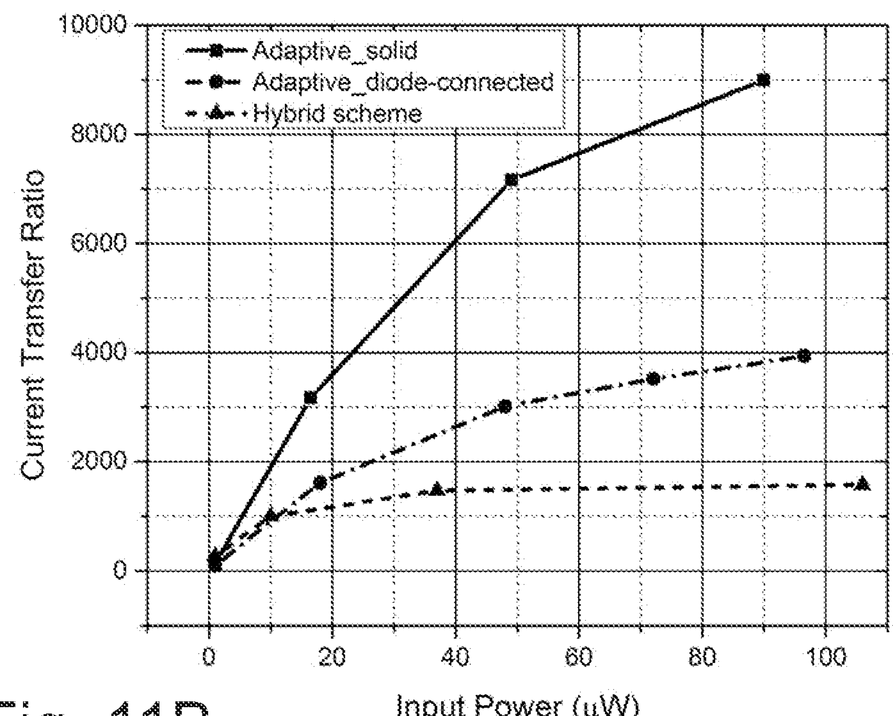


Fig. 11B

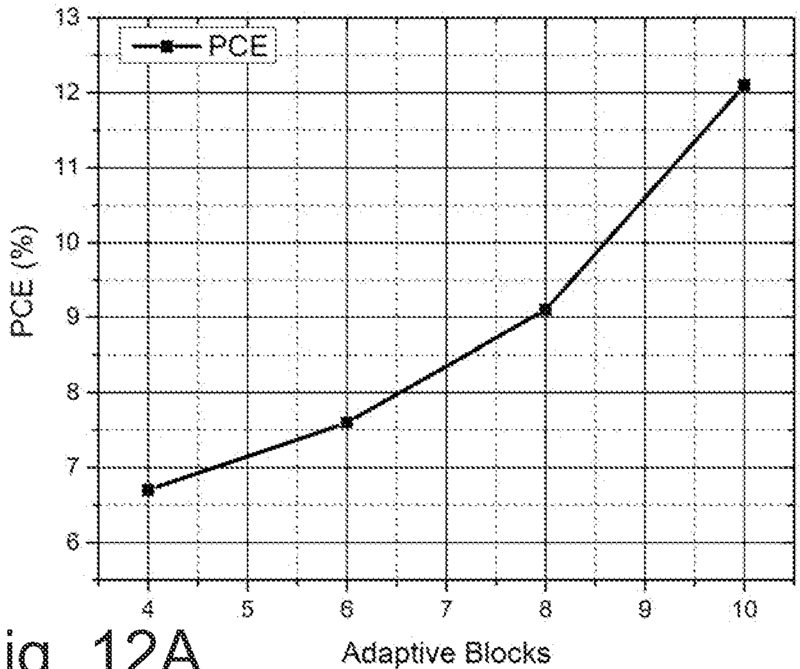


Fig. 12A

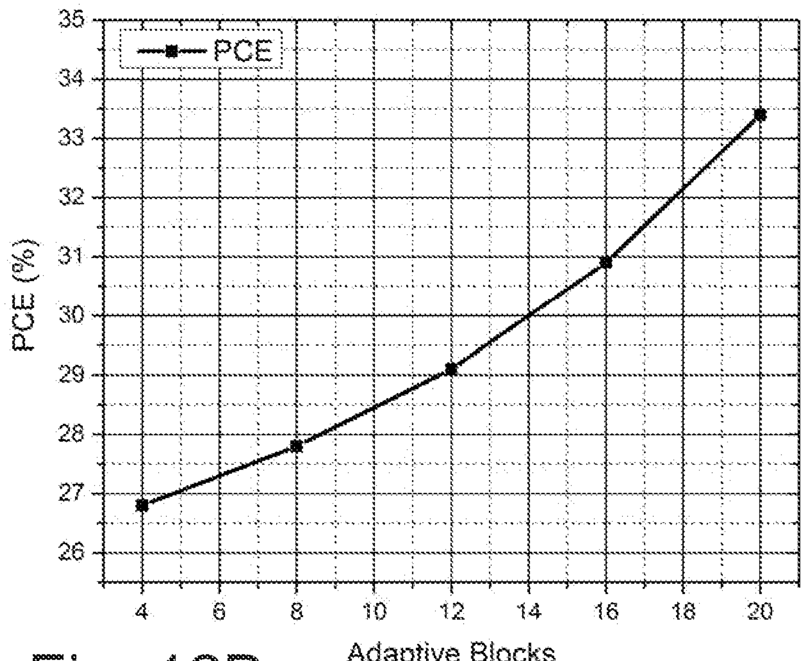


Fig. 12B

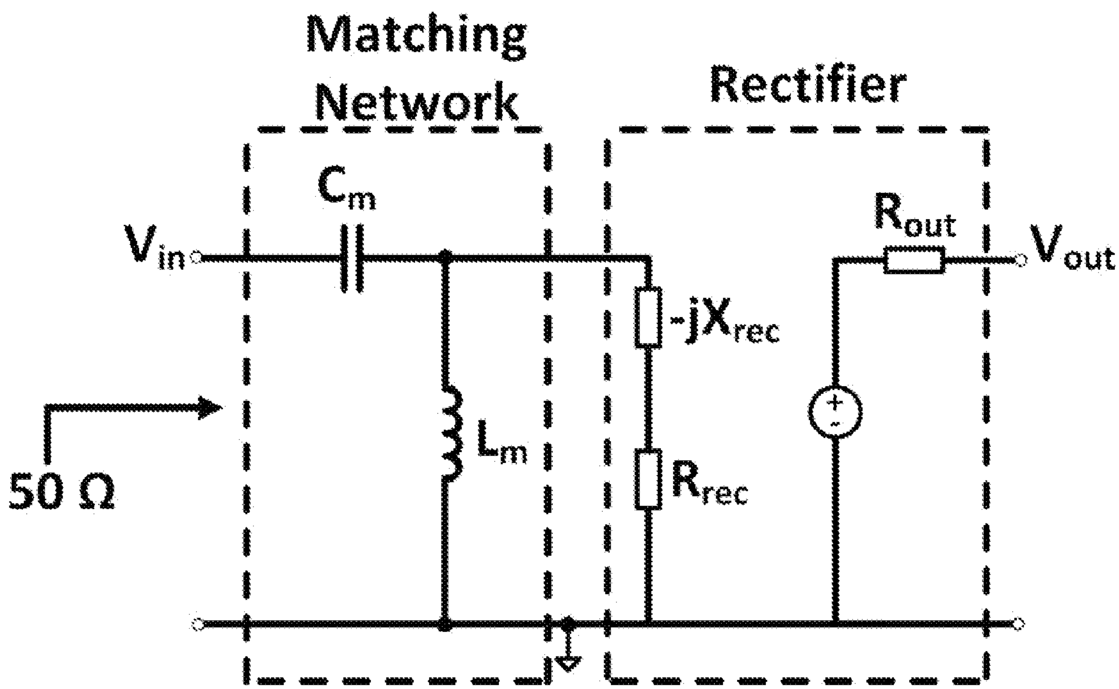

Matching Network
Rectifier
C_m
V_{in}
R_{out}
V_{out}
$-jX_{rec}$
L_m
R_{rec}
50 Ω

Fig. 13

RF-DC POWER CONVERTER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 USC 119(e) of U.S. provisional application Ser. No. 62/011,957 filed Jun. 13, 2014.

TECHNICAL FIELD

[0002] Rectification, particularly for RF energy harvesting.

BACKGROUND

[0003] The vision of realizing Internet of Things (IoT) pervasively connecting large number of sensors and devices requires development of novel solutions that scavenges ambient energy to supply the power required for the operation of the sensors. Relying on batteries as the source of energy for wireless sensors impose several limitations including the need for routine maintenance/charging of batteries, operation interruption and cost involved in replacing batteries specially those employed in harsh environments, and challenges of scaling of battery-powered wireless sensors to millions of nodes. RF energy from ambient sources can be used to power efficiently the sensor networks with or without batteries. In addition, they can also be used to partially/fully charge other portable electronic devices to extend their battery life.

[0004] There is accordingly a growing interest in harvesting ambient energy to partially/fully supply the energy required for the operation of portable electronic devices. Scavenging energy from the ambient electromagnetic wave referred as RF energy harvesting is one of the most popular method for powering low-power wireless sensors. As most of today's integrated circuits are fabricated in CMOS technology, it is highly desirable to integrate RF energy harvesting systems with the rest of the system on a single CMOS chip for reduced cost and small form factor. RF powered devices are widely used in wireless sensor networks operating at power levels of 10 to 100's of μW. RF energy harvesting can be used in applications where the traditional energy sources such as light, vibrations are not available.

[0005] In an RF energy harvesting system **20** as shown in FIG. **1**, an antenna **22** receives the incident RF signal, an impedance matching circuit **24** maximizes the power transfer from the antenna to the power converter **26**, and a RF-DC power conversion circuit **26** converts the incident RF power to DC output power. The output DC voltage is stored in an energy storage component **28** (battery or capacitor) or can directly power the wireless sensors. The major challenge of scavenging RF energy is the limited signal strength of the RF waves and the low efficiency of the harvesting circuit at low input power.

[0006] The radiated signals are received by the RF energy harvesting system **20** and converted into a DC output voltage which is used to power-up the system. The radiated signals have to adhere to the regulation standards set by the federal communication commission (FCC). The unlicensed industrial, scientific and medical (ISM) band with a center frequency of 915 MHz operating at 902-928 MHz with a maximum effective isotropic radiated power (EIRP) of 4 W can be used for RF energy harvesting. The major challenge of scavenging RF energy is the limited signal strength of the RF waves and the low efficiency of the harvesting circuit. The signal strength is limited due to the attenuation in the signal due to the free space loss. Also, the power at the transmitter level cannot be increased without violating the FCC guidelines. Hence modification has to be done at the receiver side. The power consumption for the commercial sensor network nodes vary based on the manufacturers and has been estimated by various authors to be around 10 to 100 μW depending on the sensing application and the radio protocol. A multi-volt supply voltage is typically required for the operation of the sensor circuitry.

[0007] The power harvester unit **20** comprising a multi-stage rectifier **26** is a key component in RF energy harvesting systems. It converts the incoming weak RF signal into a DC voltage. The performance of the rectifier unit **26** can be evaluated based on its power conversion efficiency (PCE) which is the ratio of power delivered to the load to the input power, based on sensitivity i.e. the minimum input power required for production of a DC voltage at the output and finally based on output DC voltage levels. To increase rectifier's PCE, the energy losses such as those introduced by the non-zero ON resistances of the rectifying devices must be reduced. To increase sensitivity and output voltage levels, rectifying devices with lower threshold voltages are required. Hence, these performance parameters of the power harvester are strongly affected by the threshold voltage of the rectifying devices. The power level has to exceed the threshold voltage of the rectifying device to turn on the rectifier unit in the RF-DC power conversion circuit. The minimum power is referred as the power-up threshold of the system. In terms of voltage level, a minimum input voltage is required for the circuit operation and is referred as the dead-zone of the rectifier.

[0008] The performance of an RF energy harvesting system **20** is significantly affected by the threshold voltage of the rectifying device **26**, the voltage that is required to turn on the semiconductor devices used as rectifying devices. A rectifying device **26** with lower threshold voltage enables the operation of RF-DC power converter **26** at low input power levels significantly reducing the power-up threshold of the rectifiers, and increasing the output voltage level for the same input power. The threshold voltage of device can be reduced using different technology-based approaches for the devices including silicon-on-sapphire (SOS), schottky diodes such as silicon-titanium schottky diodes or SMS and the HSMS diodes, special low-threshold-voltage transistors in CMOS process, and floating gate transistors which store a pre-charged voltage at the gate to lower the threshold voltage. The drawback of using technology-based approaches is additional fabrication steps that increases the production cost and prevents integration of RF energy harvester in mainstream Complementary Metal-Oxide-Silicon Integrated Circuits (CMOS ICs). Active/passive circuit techniques can be alternatively used to reduce the threshold voltage of the device. Active technique requires an external power source or secondary battery and is generally used in active sensors or active RFID. This enables more sophisticated applications at the price of increased cost and maintenance. Passive techniques do not require an additional source of energy but may require additional circuit where an auxiliary rectification chain is used to generate the compensating threshold voltage for the main RF-DC power conversion circuit. The auxiliary chain requires additional power and occupies additional area. An internal threshold voltage cancellation circuit was introduced in Kocer et al. where the compensating voltage was generated passively and stored in a capacitor that is applied at the

gate-source terminal of the MOS transistor. This technique requires a large resistance and high capacitance value which leads to a large area on the chip. A self-biasing technique consisting of an off-chip high impedance resistive network was used by Li et al. to provide DC biasing voltages. Another technique can be using floating gate transistors storing a pre-charged voltage at the gate lowering its threshold voltage. The threshold voltage can be varied by changing the body-source potential of the transistor. This technique requires an additional pre-charge phase making it unsuitable for fully battery-less applications. The RF-DC power conversion circuit consisting of NMOS transistors with grounded body terminal leads to an increase in the threshold with the number of stages due to the body effect. This degrades the efficiency of the power conversion circuit. The body terminal of the transistors can be dynamically controlled using additional circuit or floating well devices. The floating well technique generates undesirable substrate current. Also, a triple-well source-body connected device has high parasitic capacitance leading to reduced efficiency. A cross-coupled differential scheme was used in Sciorcioni et al. consisting of triple-well NMOS and standard PMOS transistors to reduce the threshold voltage. A self-compensation scheme based on the Dickson topology was introduced in Curty et al. consisting of triple-well NMOS transistors to provide individual body biasing. The compensating voltage was provided by connecting the gate terminal to later stages. The design of the power converter in the works was focused on only reducing the threshold voltage neglecting the key role played by the reverse leakage current in introducing power losses. The reduction in threshold voltage increases the reverse conduction current causing additional loss.

[0009] To address the trade-off between the reduced threshold voltage and increased leakage current, Lee et al. proposed use of high speed comparators to control the reverse leakage current. The use of comparator increases the power consumption and limits the usefulness of this technique to low-frequency applications. Dynamic CMOS Dickson pump has been designed in previous works to eliminate the V_{th} drop while reducing the reverse leakage current. These circuits are designed for digital application with no emphasis on low-power operation. Differential-drive (**4**T-cell) architecture with the cross coupled bridge configuration and its variant has been used in previous works to reduce the threshold voltage as well as lower the leakage current. Differential circuit requires a PCB balun for the single-ended to differential conversion or differential antenna. Also, the differential circuit requires triple-well NMOS transistors and larger number of rectifying devices for the same number of stages compared with single-ended one.

SUMMARY

[0010] A power conversion circuit is provided having a first input line and a second input line, the first and second input lines configured to receive an alternating voltage differential between the first and second input lines, a multi-stage rectifier comprising transistors arranged in series, each transistor having a gate, a source and a drain, adjacent transistors of the series being connected so that for adjacent p-type transistors the drain of the left p-type transistor is connected to the right adjacent source of the right p-type transistor and source of the right p-type transistor is connected to the left adjacent drain of the left p-type transistor, for adjacent n-type transistors the source of the left n-type transistor is connected to the right adjacent drain of the right n-type transistor and drain of the right n-type transistor is connected to the left adjacent source of the left n-type transistor, for a p-type transistor adjacent to an n-type transistor the source of the right p-type transistor is connected to the source of the left adjacent n-type transistor and drain of the left p-type transistor is connected to the drain of the right adjacent n-type transistor to form a junction, each junction being connected to one of the first input line and the second input line via a capacitor, with adjacent junctions having one junction of the adjacent junctions connected to the first input line and the other junction of the adjacent junctions connected to the second input line, the gate of each transistor of the multi-stage rectifier being connected to a respective junction that is not a junction formed by the connection of that transistor to an adjacent transistor but a junction in the previous stage for the p-type transistor or later stage for the n-type transistor, at least one of the transistor in the multi-stage rectifier being p-type and at least one being n-type.

[0011] In various embodiments, there may be included any one or more of the following features: There may also be an auxiliary chain of p-type transistors, each auxiliary transistor having a gate, a source and a drain, each transistor of the auxiliary chain being connected to a p-type transistor of the multi-stage rectifier in the main chain, so that the gate of the respective auxiliary transistor is connected to the source of the respective transistor in the main chain, the source of the respective auxiliary transistor is connected to the gate of the transistor in the main chain and also connected to the previous stage junction of the main chain which is N transistors away from the respective transistor, and the drain of the respective auxiliary transistor is connected to the drain of the respective transistor or to the junction of the later stage transistor in the main chain. There may also be a diode connected transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of previous stages which is N transistors away from the respective transistor. There may also be an auxiliary chain of n-type transistors, each auxiliary transistor having a gate, a source and a drain, each transistor of the auxiliary chain being connected to an n-type transistor of the multi-stage rectifier in the main chain, so that the gate of the respective auxiliary transistor is connected to the source of the respective transistor in the main chain, the source of the respective auxiliary transistor is connected to the gate of the transistor in the main chain and also connected to the later stage junction of the main chain which is N transistors away from the respective transistor, and the drain of the respective auxiliary transistor is connected to the drain of the respective transistor or to the junction of the previous stage transistor in the main chain. There may also be a diode connected transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of later stages which is N transistors away from the respective transistor.

[0012] There is also provided an auxiliary chain of transistors, each auxiliary transistor having a gate, a source and a drain, each transistor of the auxiliary chain being connected to a respective transistor of a main chain of a multi-stage rectifier in the main chain, so that the gate of the respective auxiliary transistor is connected to the source of the respective transistor in the main chain, the source of the respective auxiliary transistor is connected to the gate of the transistor in the main chain and also connected to the later stage junction of the main chain which is N transistors away from the respective transistor in the case that the respective transistor is

n-type, or to the earlier stage junction of the main chain which is N transistors away from the respective transistor in the case that the respective transistor is p-type, and the drain of the respective auxiliary transistor is connected to the drain of the respective transistor or to the junction of a previous stage transistor in the main chain, in the case that the respective transistor is n-type, or to the junction of a later stage transistor in the main chain, in the case that the respective transistor is p-type.

[0013] In various embodiments, there may be included any one or more of the following features: the transistors of the main chain and auxiliary chain may be n-type and there may also be a p-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of later stages, such that the gate of the additional p-type auxiliary transistor is connected to the gate of the n-type auxiliary transistor and the source of the n-type and p-type auxiliary transistors are connected, and the drain of the p-type auxiliary transistors is connected to junction of the main chain which is at 'N' later stages from the respective transistor. The transistors of the main chain and auxiliary chain may be p-type and there may also be an n-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of earlier stages, such that the gate of the additional n-type auxiliary transistor is connected to the gate of the p-type auxiliary transistor and the source of the n-type and p-type auxiliary transistors are connected, and the drain of the n-type auxiliary transistors is connected to junction of the main chain which is at 'N' earlier stages from the respective transistor. There may also be a diode connected p-type or n-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of later stages which is N transistors away from the respective transistor. There may also be a diode connected p-type or n-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of earlier stages which is N transistors away from the respective transistor.

[0014] In any of the above embodiments, there may be included any one or more of the following features: There may also be an additional transistor connected in series with the multistage rectifier, the additional transistor having a gate, a source and a drain, the gate of the additional transistor being connected to the drain of the additional transistor. The gate of each transistor in the main chain may be connected to the junction of previous stages for p-type transistor and later stages for n-type transistor. N of the transistors in the multistage rectifier arranged in series may be n-type and all but N of the transistors in multistage rectifier arranged in series may be p-type. The second input line may be grounded. The body terminal of each p-type transistor may be connected to the respective drain and the body terminal of each n-type transistor may be either grounded or connected to the respective drain terminal.

[0015] These and other aspects of the device and method are set out in the claims, which are incorporated here by reference.

BRIEF DESCRIPTION OF THE FIGURES

[0016] Embodiments will now be described with reference to the figures, in which like reference characters denote like elements, by way of example, and in which:

[0017] FIG. **1** is a block diagram showing energy flow from a receiver through a power harvester to a load;

[0018] FIG. **2**A is a schematic diagram of a prior art half-wave rectifier using a diode;

[0019] FIG. **2**B is a schematic diagram of a prior art half-wave rectifier using diode-connected NMOS;

[0020] FIG. **2**C is a schematic diagram of a prior art half-wave rectifier using diode connected PMOS;

[0021] FIG. **2**D is a schematic diagram of a prior art voltage doubler full wave rectifier using diodes;

[0022] FIG. **2**E is a schematic diagram of a prior art voltage doubler full wave rectifier using diode connected NMOS;

[0023] FIG. **2**F is a schematic diagram of a prior art voltage doubler full wave rectifier using diode connected PMOS;

[0024] FIG. **2**G is a schematic diagram of a prior art threshold-compensated transistor in a single-stage rectifier;

[0025] FIG. **3**A is a graph of output current with respect to input voltage for a prior art PMOS voltage doubler as shown in FIG. **2**F;

[0026] FIG. **3**B is a graph showing input and output voltage over time of the threshold-compensated transistor of FIG. **2**G;

[0027] FIG. **4**A is a schematic diagram of a prior art NMOS Dickson charge multiplier;

[0028] FIG. **4**B is a schematic diagram of a prior art PMOS Dickson charge multiplier;

[0029] FIG. **5** is a schematic diagram of a prior art forward compensated charge multiplier;

[0030] FIG. **6**A is a schematic diagram of a level-1 back compensated PMOS charge multiplier;

[0031] FIG. **6**B is a schematic diagram of a level-1 hybrid forward and back-compensated multiplier using NMOS and PMOS;

[0032] FIG. **6**C is a schematic diagram of a level-3 hybrid forward and back-compensated multiplier using NMOS and PMOS;

[0033] FIG. **7** is a contour plot of constant efficiency for input power versus level of compensation;

[0034] FIG. **8**A is a contour plot of constant efficiency for width versus number of stages for a level-1 compensated multiplier;

[0035] FIG. **8**B is a contour plot of constant efficiency for width versus number of stages for a level-3 compensated multiplier;

[0036] FIG. **9**A is a schematic diagram of a multiplier with an adaptive threshold-voltage compensation scheme using diode-connected transistors;

[0037] FIG. **9**B is a schematic diagram of a multiplier using p-type transistors with an adaptive threshold-voltage compensation scheme using solid-wired connections;

[0038] FIG. **9**C is a schematic diagram of a multiplier using n-type transistors with an adaptive threshold-voltage compensation scheme using solid wired connections;

[0039] FIG. **9**D is a schematic diagram of a multiplier using n-type transistors with an adaptive threshold compensation scheme using p-type and n-type transistors;

[0040] FIG. **10**A is a contour plot of constant efficiency for width versus number of stages for an adaptive diode-connected scheme as shown in FIG. **9**A at an operating frequency of 915 MHz;

[0041] FIG. **10**B is a contour plot of constant efficiency for width versus number of stages for an adaptive solid-wired scheme as shown in FIG. **9**B at an operating frequency of 915 MHz;

[0042] FIG. **11**A is a graph of leakage current versus input power with different schemes at 915 MHz;

[0043] FIG. 11B is a graph of current transfer ratio versus input power with different schemes at 915 MHz;

[0044] FIG. 12A is a graph of efficiency versus number of adaptive blocks for the adaptive diode-connected scheme;

[0045] FIG. 12B is a graph of efficiency versus number of adaptive blocks for the adaptive solid-wired scheme; and

[0046] FIG. 13 is a schematic diagram showing an impedance matching circuit.

DETAILED DESCRIPTION

[0047] There is provided a hybrid forward and backward threshold voltage compensation scheme for RF-to-DC power conversion. In an embodiment, PMOS transistors are used as rectifying devices in all stages except for the first few stages eliminating the need for triple-well NMOS transistors. The compensating voltage is provided by connecting the gate terminal of the PMOS transistors to previous stages, also referred to as back-compensation, and also by connecting the gate terminal of the initial few NMOS transistors to later stages. Using PMOS transistors as a rectifying device in all the stages except for the first few stages eliminate the need for triple-well NMOS transistors. Also, all the MOS transistors in the main rectification chain are compensated in the proposed scheme. In addition to the hybrid scheme, an adaptive method suitable for rectifying devices operating at low power level is proposed to control the ON/OFF operation of the MOS transistors in the main rectification chain. An auxiliary block consisting of PMOS transistor is introduced to control the switching of the MOS transistors in the main chain. The PMOS transistors in the main chain are back-compensated in the conduction phase and forward-compensated when not conducting; increasing the gate-source potential and reducing the reverse leakage. The controlling voltage of the transistors in the auxiliary chain is derived from the local node of the main chain. Moreover, a procedure for designing matching network to provide passive voltage amplification and maximum power transfer is proposed. The dead-zone of the power converter unit is obtained using Y parameter analysis and the matching circuit is designed at the point of maximum power transfer. The RF-to-DC power conversion circuit may be fabricated using conventional methods such as IBM's 0.13 μm CMOS technology.

[0048] Power Harvester Circuit

[0049] FIG. 1 shows a block diagram of the power harvester unit of an RF energy harvesting system 20. In the RF energy harvesting system shown, the signal is received by an antenna 22. An impedance matching circuit 24 comprising a high quality factor (Q) resonator is used to ensure that maximum power is transferred from the receiver to the rectifier block 26. However, the matching network itself introduces some energy losses because of the limited quality factors of on-chip passive inductors and capacitors required to match the input impedance of the rectifier to the output impedance of the antenna. The high Q resonator can also provide passive voltage amplification of the input signal. Depending on the embodiment, the high Q resonator may have a fixed frequency or may be tuneable. The next block is the RF-to-DC power conversion circuit 26 that converts the RF signal to DC voltage. The rectifier preferably operates at low input power levels while providing high power conversion efficiency. Several rectifier units may be cascaded to increase the overall output voltage, referred collectively as a voltage multiplier. There may be a power management block (not shown) to control the flow of power from the energy harvester to the load. The harvested power is then finally used to charge an energy storage device 28 such as a battery or a capacitor, which in turn powers a load 30. Alternatively, the energy storage device may be omitted and the load powered directly by the power harvester. The power management block may also be omitted with or without the energy storage.

[0050] Rectifier Circuit

[0051] In half-wave rectifiers, the rectifying device is conducting for half of the cycle, passing the input voltage to the output. However, the output voltage is lower than the input by the amount of voltage drop needed for turning ON the rectifying device. A half-wave rectifier can be implemented using diodes as shown in FIG. 2A. The voltage drop across the device depends on the threshold voltage of the diode. FIGS. 2B and 2C show half-wave rectification circuits implemented using diode-connected NMOS and PMOS transistors respectively in CMOS technology. The voltage drop in this case depends on the threshold voltage of the transistor. Both diode-connected PMOS and NMOS transistors can be used as rectifying devices. FIG. 2D shows the voltage doubler unit which is a cascade of two half-wave rectifiers. The voltage doubler rectifies the AC input in both the positive and negative cycles. Similar to the half wave rectification, the diodes are implemented by connecting the drain and the gate terminal of the MOS transistor together such that the transistor is always in saturation region in forward bias condition, as shown in FIGS. 2E and 2F.

[0052] The voltage doubler may be used as a basic unit in a power conversion circuit. FIG. 2F shows an example voltage doubler. In the voltage doubler, each of the transistors conducts only during one half of the input cycle. M_{P1} conducts during the negative phase while M_{P2} conducts during the positive phase of the input cycle. Each of the transistors goes through the sub-threshold region, inverse region and the leakage region. The maximum voltage at the output of voltage doubler is $2\,Vamp-|VTP1|-|VTP2|$, where V_{amp} is the maximum amplitude of the input signal and V_{TP1}, V_{TP2} are the threshold voltages of the diode-connected transistors M_{P1} and M_{P2} respectively. Thus the maximum possible voltage is twice the RF signal's amplitude only when the threshold voltage of the transistors is equal to zero. To understand the operation of the voltage doubler in detail, we can look at the transient analysis of the doubler circuit of FIG. 2F, as shown in FIG. 3A. There are three regions of operation of the circuit as seen from FIG. 3A. It is described as follows: the sub-threshold operation extends from $V_{in}=0$ to $V_{in}=|V_{TP}|$, where V_{in} is the input voltage. The current in this region is an exponential function of the input voltage. The inversion region extends from $V_{in}=|V_{TP}|$ to $V_{in}=V_{amp}$. The current in the in this region is a square function of the input voltage. In the inversion region, the output current reaches its peak value when $V_{in}=V_{amp}$. Finally, the leakage region extends from $V_{in}=0$ to the next $V_{in}=0$ in the negative half-cycle. The current that flows through transistor M_{P2} during this time interval is referred as reverse leakage current. Thus, the actual charge transfer mechanism is only for a short duration while other parameters such as subthreshold and reverse leakage currents have to be considered for the rest of the cycle.

[0053] Several voltage doublers can be cascaded to increase the overall output voltage. These voltage multipliers are also known as "charge pumps" and can generate a voltage several times larger than their input supply voltage. The Dickson multiplier with diode-connected transistors is commonly used for integrated applications. The Dickson multiplier of

FIG. **4**A is modified for low power energy harvesting applications by grounding the ϕ_2 (out of phase) clock terminal and applying the input signal at the ϕ_1 terminal. FIG. **4**B shows the conventional Dickson multiplier with the PMOS voltage doubler as a rectifier unit. The body terminal of the transistors is connected as shown in FIG. **4**B to further reduce the threshold voltage while the transistors are conducting. For example, in the positive phase of the input cycle, transistors M_2, M_{n-1} and M_{n+1} are conducting. The source of the transistors is at a higher potential compared to the body terminal. This reduces the threshold voltage in the conducting region. At the same time, transistors M_1, M_3 and M_n are in the reverse region (leakage operation). The gate-source and the body-source potential is zero for these transistors. Thus, the threshold voltage of transistors M_2, M_{n-1} and M_{n+1} while they are conducting is lower than the threshold voltage of the transistors M_1, M_3 and M_n which are in the reverse region in the positive input phase. Similarly, in the negative phase of the input cycle, transistors M_1, M_3 and M_n which are conducting have a lower threshold voltage than the transistors M_2, M_{n-1} and M_{n+1}.

[0054] To increase the output voltage of multi-stage rectifiers, the number of rectifier stages must be increased accordingly. However, as the number of stages increases the power conversion efficiency is reduced as larger number of the transistors dissipates more power. Also, the threshold voltage of the standard MOS transistor which lies around 450 mV in 130 nm technology, reduces the sensitivity of the power harvester block. As the number of stages in the rectifier increases, the power losses increases, reducing the overall efficiency. Too few of stages, leads to low output DC voltage even if the PCE is high. To achieve a high DC voltage, large transistors have to be used, leading to high leakage and parasitic losses whereas smaller transistor size affects the charge transfer leading to low DC voltage. The strategy while designing the multi-stage rectifier circuit of FIG. **4**B is as follows: The individual stages of the voltage doubler can be cascaded to increase the output voltage. As the number of stages increases, the output voltage increases. With the increase in the number of stages, the PCE decreases and the output voltage saturates. Hence the transistors as well as the pumping capacitors are scaled while increasing the stages. The scaling is done to maintain the incremental voltage per stage and the PCE relatively constant with the increase in the number of stages. Thus the PCE can be maintained with proper device scaling while increasing the DC voltage for a constant output power. The scaling of width and the pumping capacitance with the stages results in impedance looking into the rectifier to be unchanged so that the input power and thus the PCE remains constant. Thus, when designing a multistage rectifier unit one can optimize of number of stages and width of the transistors to maximize the PCE for a given output voltage.

[0055] The standard Dickson multiplier can be modified for designs involving energy harvesters where the input voltage is low. FIG. **4**A shows an N-stage conventional Dickson multiplier. A threshold self-compensation technique was described by Dickson. The gate of the transistor in this technique is connected to the adjacent source of the transistor instead of the traditional diode-connected structure. Thus, providing bias voltage equivalent to the incremental voltage across each stage. Based on this technique, a forward compensated topology was implemented by Papotto et al. where the bias voltage was increased by extending the gate length connection. FIG. **5** shows the basic forward compensated NMOS topology.

[0056] Threshold voltage reduction techniques requiring additional circuits are not suitable for integrated low power energy harvesting applications as these circuits occupy large areas and cause additional power dissipation. Passive threshold voltage reduction technique such as the self-compensation method of FIG. **5** does not require additional circuit and can reduce the threshold voltage. In the self-compensation method, the threshold voltage of the diode-connected NMOS transistors increases with the stages due to the body effect. The body effect can be dynamically controlled using additional circuits but generates undesirable substrate current. Another alternative is using triple-well process to individually bias the body terminal of NMOS transistors and reduce the threshold voltage variation. Additional parasitic capacitance is introduced due to the well structure increasing the losses at each node and affecting the overall efficiency.

[0057] Hybrid Forward and Back-threshold compensated power converter

[0058] In order to eliminate the need for triple-well processes, we propose a threshold voltage compensation technique scheme as described below. PMOS transistors are used instead of NMOS transistors as rectifying devices. As each PMOS transistor has its own n-well, the body of PMOS transistor can be biased individually without the necessity of a triple-well CMOS process. Unlike an NMOS transistor which needs a higher potential at the gate terminal to offset the threshold voltage, a PMOS transistor requires negative gate-source potential. Therefore, the threshold voltage of PMOS transistors can be reduced by connecting the gate potential to the previous node rather than later node. As shown in FIG. **6**A, alternating input voltage V_{in} is applied on first input line **100** to odd-numbered capacitors $C_1, C_3, \ldots C_n$. Ground voltage is applied on second input line **102** to even numbered capacitors $C_2, \ldots C_{n-1}$. Capacitor C_{n+1}, while also even-numbered, is shown as connected to ground by a separate line. A third line **104** accumulates voltage for the output and is connected to ground at one end and to output at the other. In this and other figures, the end of the line having more negative voltage, which in the embodiments shown is ground, is shown at the left of line **104** and the end of the line having more positive voltage, which in the embodiments shown is the output, is shown at the right of line **104**. The capacitors are each connected to line **104**, and are numbered in the order in which they are connected to line **104** from left to right. Each capacitor maintains a respective voltage differential between the respective input line it is connected to and the part of line **104** it is connected to. This voltage differential varies over time as current flows through line **104** between capacitors. Line **104** comprises transistors $M_1, M_2, M_3, \ldots M_{n-1}, M_n, M_{n+1}$ arranged in series, a transistor being arranged between each pair of adjacent capacitors and between capacitor C_1 and ground. Adjacent transistors define junctions **106**, the capacitors being connected to the junctions. The body terminal of each transistor is connected to the drain terminal of the same transistor, as shown by dotted lines. The gate of the first transistor (for n-level compensation, the first 'n' transistors) and the last transistor are connected to their respective drains. The gates of the other transistors are connected to the drain of the transistor n+1 transistors to the left of the respective transistor. The proposed scheme as shown in FIG. **6**A reduces the threshold voltages of all PMOS transistors except the first

one leading to an increased output voltage. For an n-level compensation, for the proposed scheme, there will be 'n' initial PMOS transistors that will be uncompensated as seen from FIG. **6**A To solve this problem, 'n' uncompensated PMOS transistors are replaced by NMOS transistors with grounded body terminals as seen from FIG. **6**B. As shown in FIG. **6**B, the first transistor is an NMOS transistor with a source connected to the source of the PMOS transistor to its right to define a junction and has a gate connected to the junction n stages to the right of the junction defined by its source. That is, the gate is connected to the junction defined by the source of the PMOS transistor **2** (i.e, n+1) transistors to the right. The other transistors are PMOS and, apart from the last, each has a gate connected to a junction n stages to the left of the junction defined by its source. For the purposes of the preceding statement and statements about junctions elsewhere in this document, the grounded end of line **104** can be considered to be a junction **106**A one stage from the junction defined by the connection of M_1 and M_2. Thus the compensating voltage is provided by connecting the gate terminal to later stages for the first few NMOS transistors and connecting the gate terminal to previous stages for PMOS transistors. The scheme shown in FIG. **6**A and FIG. **6**B is level-1 compensation. The compensation level can be increased by connecting the gate terminal of PMOS to the source terminals of the transistor of the following stage rather than the source of its immediate neighbor. The last transistor of the multiplier is left uncompensated to reduce the leakage. FIG. **6**C shows the proposed level-3 hybrid forward- and back-compensated multiplier. As shown in FIG. **6**C, the first **3** (i.e., n) transistors are NMOS transistors with grounded body terminals. Each NMOS (more generally, n-type) transistor has its source on the left and drain on the right, and each PMOS (more generally, p-type) transistor has its drain on the left and source on the right, where "left" and "right" are defined so that that the end of line **104** with more positive voltage is the "right", as shown in the figures. "Earlier" and "later" can also be used to mean "left" and "right". While ground is shown in the figures to the left and the output to the right, the ground could also be to the right and the output to the left. See below for a discussion of the definitions of "source" and "drain". The gates of these first **3** NMOS transistors are connected to the respective junctions **106** three (that is, 'n') stages to the right of the junctions defined by their respective sources. The remaining transistors except the last are PMOS transistors with gates connected to the junctions **106** three (that is, 'n') stages to the left of the junctions defined by their respective sources. Increasing the level of compensation leads to reduction in the threshold voltage which improves the forward conduction but also leads to increased reverse leakage current degrading the rectifier's PCE. Only odd level compensation is used as it maximizes the source-gate potential of PMOS transistors due to the alternating voltage phase with successive nodes.

[0059] To find the optimum number of stages and level of compensation, extensive simulations were conducted. FIG. **7** shows the efficiency contour plots with different level of compensation and input power level. Maximum PCE at the lowest input power level is obtained when the level of compensation is one. As the level of compensation increases, the reverse current increases which causes additional power loss and degradation in efficiency. Hence level-1 compensation gives the maximum efficiency while level-3 or higher is advantageous in reducing the threshold voltage of the RF-DC power conversion circuit. FIG. **8**A shows the constant efficiency contour plot as a function of transistor width and the number of stages for level-1 compensation. Eight-stage of doubler design equivalent to 16-stage rectifier with transistor width of 13-μm and fifteen-stage of doubler design equivalent to 30-stage rectifier with transistor width of 28 μm gives the highest efficiency contour. The former one is preferred due to lesser area on the chip. The level-1 and level-3 compensated multi-stage rectifier are referred to as efficiency circuit and voltage circuit respectively Similarly for the voltage circuit constant efficiency contour plot as a function of width and the number of stages is plotted as shown in FIG. **8**B. Twelve-stage of doubler design equivalent to 24-stage rectifier with transistor width of 8 μm is selected based on the plot. For level-3 compensation, more body-grounded NMOS transistors are required compared with the level-1. Also, the reverse leakage loss is higher for level-3 compensation due to the larger compensating voltage compared with the level-1 compensation. Increasing the level of compensation lowers the minimum input voltage requirement whereas increasing the number of stages while lowering the width of the transistors was based on the design strategy discussed earlier.

[0060] During the positive input phase, transistors M_2, M_{n-1} and M_{n+1} in FIGS. **6**A-**6**C are conducting. Since the gate terminals are connected to the previous node V_{SG} in the positive phase (conduction) is relatively high compared to the conventional Dickson multiplier. However, in the negative phase when the transistors M_2, M_{n-1} and M_{n+1} should ideally be not conducting, the V_{SG} is higher compared to the conventional case. Thus the hybrid forward and back-threshold compensated scheme is effective in increasing the forward conduction current but increases the reverse leakage current at the same time. As seen in FIG. **7**, with the increase in the level of compensation the PCE degrades. The simulated maximum PCE of 28% degrades to 11% from level-1 compensation to level-3 compensation respectively. To ameliorate this issue an adaptive scheme is proposed to control the reverse leakage current.

[0061] Especially at extremely low input power (e.g. micro-watts power level), the reverse leakage current has a significant adverse effect on the PCE and the output DC voltage of an RF rectifier as proven by the following analysis. Considering a threshold-compensated transistor of a single-stage rectifier shown in FIG. **2**G driven by an input source $V_{in}=V_a \sin \omega t$ assuming the compensation voltage is modeled by V_C and its input and the output steady-state voltage waveforms shown in FIG. **3**B, the overall PCE is defined as

$$PCE = \frac{P_{out,forward} - P_{leakage}}{P_{input}} \tag{1}$$

[0062] where $P_{out,forward}$ is the output power delivered to the load when transistor is forward-biased, $P_{leakage}$ is the output power lost due to leakage when transistor is reverse-biased, and P_{input} is the input power. The forward region extends from $t=t_1$ to $t=\pi-t_1$ with the current $I_d(t)$ through the MOS transistor M_1 as seen in FIG. **3**B.

$$\frac{P_{out,forward}}{P_{input}} = \tag{2}$$

-continued

$$\frac{\frac{1}{\pi-2t_1}\int_{t_1}^{\pi-t_1} V_{out}\cdot I_d\cdot dt}{\frac{1}{\pi-2t_1}\int_{t_1}^{\pi-t_1} V_{in}\cdot I_d\cdot dt}=\frac{\frac{1}{\pi-2t_1}\int_{t_1}^{\pi-t_1}(V_a-V_{TH}+V_c)\cdot dt}{\frac{1}{\pi-2t_1}\int_{t_1}^{\pi-t_1} V_a\sin\omega t\cdot dt}$$

Assuming the ripple voltage variation A V is much smaller than the average output voltage V_o, the output voltage for the one-stage rectifier can be expressed as $V_o=V_a-V_{TH}+V_C$ where V_{TH} is the threshold voltage of the transistor. Performing integration on (2) gives the ratio of the output power in the forward region to the input power as

$$\frac{P_{out,forward}}{P_{input}}=\frac{\omega\cdot(\pi-2t_1)\cdot(V_a-V_{TH}+V_c)}{2V_a\cos\omega t_1} \tag{3}$$

[0063] The value of t_1 lies between $0<t_1<\pi/2$ based on the value of $V_{TH}-V_C$. The time t_1 indicates the onset of inversion region and is close to zero when the compensating voltage is near the threshold voltage and will be closer to $\pi/2$ when the compensating voltage is near-zero value. As seen in (3), the ratio of the output power in the forward region to the input power increases with increased voltage compensation in the forward region. In the reverse-biased region, the leakage current is expressed as

$$I_{leak}(t)=I_o\cdot(W/L)\cdot e^{(V_{gs}-V_{TH})/\eta V_T}\cdot(1-e^{-V_{ds}/\eta V_T}) \tag{4}$$

[0064] Replacing the gate-source bias voltage by V_C, source-drain bias by $V_{in}(t)-V_{out}$ and V_{in} by V_a sin wt, the leakage current as a function of time can be expressed as

$$I_{leak}(t)=I_o\cdot(W/L)\cdot e^{(V_c-V_{TH})/\eta V_T}\cdot(1-e^{(V_a\sin\omega t-V_a+V_{TH}-V_c)/\eta V_T}) \tag{5}$$

[0065] where $(\pi-t_1)<t<(2\pi+t_1)$. With increase in the compensation, the power loss increases due to the higher leakage current. As seen in (3) and (5), the ratio of the output power in the forward region to the input power even though increases with larger threshold-voltage compensation, the losses in the leakage region is higher due to the increased compensation. This indicates the fundamental trade-off between the level of threshold-voltage compensation and the leakage current of the transistors.

[0066] In a field effect transistor, the "source" and "drain" terminals are defined by the direction of flow of charge carriers when the transistor is "on": charge carriers flow from the source to the drain. For an n-type transistor, the charge carriers are electrons and for a p-type transistor the charge carriers are holes. As electrons flow from negative to positive, the source of an n-type transistor is at a lower voltage than the drain and vice versa for a p-type transistor. FETs do not necessarily have any asymmetry between the source and drain terminals beyond this. In the present system, the relative voltages of the source and drain terminals reverse in the normal course of events, as the system is exposed to alternating current in order to rectify it. There are two possible approaches to defining which terminal is the "source" and which terminal is the "drain" in this circumstance. One possible approach is to say that which terminal is the "drain" and which terminal is the "source" varies over time depending on which terminal is at the higher voltage. Thus, by this first definition, the source of an n-type transistor is whichever of the source and drain terminals has the lower voltage at any given moment, and for a p-type transistor whichever has the higher voltage at a given momentA second approach, however, is possible where the desired conduction is in a particular direction only. In the present system, conduction in one direction is desirable and conduction in the other ("leakage") is undesirable, thus the source can be defined according to which terminal is the source when current flows through the transistor in the desired direction; which terminal is considered the "source" and which terminal is considered the "drain" does not change over time in this approach despite the change in voltages. In the discussion here concerning the source-gate voltage (V_{SG}), the first approach is used, i.e. the source-gate voltage is the voltage between the gate and whichever of the source or drain terminals that has the higher or lower voltage at a given time depending on if the transistor is p-type or n-type. In addition, while the sign of a source-gate voltage difference required to operate a transistor depends on whether the transistor is p-type or n-type, V_{SG} is discussed as if the voltage to operate the transistor is always positive for p-type transistor and negative for n-type transistor. For other purposes in this document including the claims, a version of the second approach to defining which terminal is the source and which is the drain is used in which the direction of desired current is based on the desired current direction through the device as a whole. Thus, throughout the figures, p-type transistors are shown as having their sources to the left and n-type transistors are shown as having their sources to the right.

[0067] A diode-connected transistor is a transistor in which one of the source and drain terminals is connected to the gate to cause the transistor to act as a diode. A diode connected FET allows charge carriers to flow from the terminal not connected to the gate to the terminal connected to the gate, if sufficient voltage is applied, and blocks charge carriers from flowing in the opposite direction. The diode connected transistor is diode connected because it is desired that current flow in one direction is allowed and in flow in the other direction blocked. Thus, following a version of the second approach above to defining which terminal is the source and which terminal is the drain based on desired current through the individual transistor, the source or drain terminal of a diode connected transistor that is connected to the gate would be by definition the drain of the diode connected transistor. However, in this document it is the desired current through the device as a whole that is used, thus in e.g. FIG. **9**A transistor M_{na} is diode-connected and the terminal connected to the gate is depicted as the source.

[0068] To investigate the effect of the level of threshold-compensation on the PCE of multi-stage hybrid threshold-compensated rectifiers, level-1 rectifier which is connecting the gate terminal to one previous node for the PMOS transistors (FIG. **6**A) and level-3 rectifier which is connecting the gate terminal to three previous nodes (FIG. **6**C) for the PMOS transistors are simulated to obtain constant maximum efficiency contour plots as shown in FIG. **7**. Increasing the level of compensation leads to reduction in the threshold voltage which improves the forward-conduction but also increases the reverse leakage current. In the multipliers as shown in FIGS. **6**A and **6**C, during the positive input phase, transistor M_n is forward-biased. Since the gate terminals are connected to the previous node, V_{sg} when forward-biased is higher compared to that of the conventional diode-connected case with no threshold-voltage compensation which increases the ratio of output power in the forward region to the input power. However, when the transistor M_n is reverse-biased, the V_{sg} is

higher compared to the conventional diode-connected case increasing the reverse leakage current of the reverse-biased transistor. This can also be explained by the efficiency contour plots of the hybrid scheme as seen from FIG. **7**. The contour plots are simulated for constant efficiency with different level of compensation and input power levels. As seen from FIG. **7**, though with the increase in the level of compensation the threshold voltage reduces, the efficiency degrades at the same time which is due to the increased reverse leakage current. The simulated maximum PCE of 28% degrades to 11% from level-1 compensation to level-3 compensation respectively. Accordingly an adaptive scheme is proposed to control the threshold voltage and the reverse leakage current of the rectifying device dynamically to improve the PCE over a wide range of input power. Ideally, the threshold voltage of the rectifying device should be zero when the transistors are forward-biased while the threshold voltage should be high when the transistors are reverse-biased to prevent any leakage or the losses associated with it.

[0069] We propose an adaptive forward and backward threshold-voltage compensation scheme that use minimal additional circuitry to increase the threshold-voltage compensation when transistors are forward-biased and decrease the compensation voltage when they are reverse-biased. The PMOS transistors in the main rectification chain are back-compensated when forward-biased and forward-compensated when reverse-biased; increasing the forward-current and reducing the reverse leakage current dynamically.

[0070] Proposed Adaptive Threshold Voltage Compensation

[0071] The hybrid forward and back-compensated topology described above can be made adaptive using an auxiliary block controlling the gate-source voltage of the MOS transistors in the main rectification chain. The auxiliary structure may be realized using all PMOS transistors to allow for individual body biasing. Preferably the auxiliary blocks are designed using minimum number of PMOS transistors so that the power losses do not increase considerably due to the additional blocks. The controlling voltage of the transistors in the auxiliary chain is derived from the local node of the main rectification chain. Two possible implementation of the proposed adaptive threshold voltage compensation scheme are discussed in the following section, one using diode-connected PMOS transistors and the other solid-wired connection to adaptively adjust the level of the threshold-voltage compensation.

[0072] Using Diode-Connected Transistor for Back-Compensation

[0073] FIG. **9**A shows the hybrid forward and back-threshold compensated rectifier using diode-connected transistors for back-compensation. The back-compensation reduces the threshold voltage when the transistors are forward-biased and forward-compensation reduces the reverse leakage current when reverse-biased with the control signal derived from the local node. In the embodiment shown the last transistor M_{n+1} is left uncompensated to reduce the leakage. During the negative input phase, in which the transistor M_n is forward-biased, the transistor M_n is back-compensated by the diode-connected transistor M_{na} while the V_{SG} terminal voltage for the transistor M_{nb} lies below its threshold voltage resulting in transistor M_{nb} turned OFF. In comparison to the embodiment shown in FIG. **6**B, diode-connected transistor M_{na} lies on the line connecting to the gate of transistor M_n. Transistor M_{nb} lies on a different line not corresponding to a line in FIG. **6**B, providing a forward connection for the gate of transistor M_n when transistor M_{nb} is active. In the embodiment shown in FIG. **9**A p-type transistors are used, but n-type could also be used. Additional transistors of the opposite type may be used at one end as in FIG. **6**B. The back-compensation for the transistor M_n in the main chain enhances the forward current. During the positive input phase, in which the transistor M_n is reverse-biased, the V_{SG} terminal for transistor M_{nb} is enough to turn ON the forward connection thus reducing the V_{SG} bias of the transistor M_n to zero resulting in a reduced leakage current. FIG. **10**A shows the efficiency contour plot for the adaptive diode-connected scheme as a function of width and the number of stages of the rectifier. Generating contour plots are an effective way to optimize the number of stages and the width of the transistors to maximize the PCE while obtaining the required voltage. Twelve-stage of voltage doubler design equivalent to 24-stage rectifier with transistor width of 11 μm gives the highest efficiency contour. The width of the diode-connected transistor in the auxiliary chain should be comparable to the width of the transistors in the main rectification chain so that it provides low forward-resistance when the transistors are conducting. In an embodiment, the width of the diode connected transistor in the auxiliary chain may be 8 μm. The auxiliary transistor used for forward compensation to control the reverse-leakage is selected in an embodiment to be 480 nm, an order of magnitude smaller than the diode-connected transistor to minimize their power consumption and reduce the parasitic at the nodes of the main rectification chain. Larger transistor widths are avoided to reduce the parasitic at the nodes of the main rectification chain.

[0074] Also, for the diode-connected scheme, the auxiliary block is added for every alternate transistor starting from the later stages and adding the blocks towards the initial stages. The maximum PCE increases with the addition of the adaptive auxiliary blocks.

[0075] Using Solid Connection for Back-Compensation

[0076] FIG. **9**B shows the adaptive hybrid topology using solid wired connection instead of the diode-connected transistor for reducing the threshold voltage. When the transistors are in the conduction phase (forward biased) they are back-compensated with solid wired connection instead of the diode-connected transistors which prevents the forward-losses associated with it. In the embodiment of FIG. **9**B, as compared to FIG. **9**A, the transistors M_{na}, $M_{n-1})_a$ etc. are omitted and replaced by a solid wire connection as in FIG. **6**B, but the transistors M_{nb}, $M_{(n-1)b}$ etc. are retained. In the embodiment shown in FIG. **9**A p-type transistors are used, but n-type could also be used. Additional transistors of the opposite type may be used at one end as in FIG. **6**B. When the transistor M_n is reverse-biased (not in the conduction phase), the V_{sg} terminal voltage for the auxiliary transistor M_{nb} is large to turn ON the forward-connection and reduce the source-gate bias of transistor M_n. This decreases the reverse leakage current greatly. FIG. **10**B shows an efficiency contour plot for the solid-wired scheme as a function of width and the number of stages of the rectifier. Twelve stages of doubler design equivalent to 24-stage rectifier with transistor width of 10 μm gives the maximum efficiency contour. The efficiency contour plot for the solid-connection follows similar trend as the diode-connected one. With the increase in the width of the transistors while maintaining the number of stages, the efficiency initially increases and then degrades due to the increased parasitic losses. Similarly, when the width of the transistor is kept constant and the number of stages is

increased, the efficiency initially increases and then degrades as more number of stages is added due to the increased power loss with additional stages. Coupling capacitor value of 4 pF is selected as it has a very modest impact on the rectifier's efficiency.

[0077] Further embodiments are shown in FIG. **9**C and FIG. **9**D. The embodiment of FIG. **9**C operates in the same way as the embodiment of FIG. **9**B but uses n-type transistors instead of p-type. Accordingly, the solid wired connections to the gates of the transistors in the main chain are to the right instead of to the left. FIG. **9**D is an embodiment in which the connections to the gates of the transistors of the main chain are each controlled by two transistors. However, unlike in FIG. **9**A, one of these two transistors is p-type and the other is n-type. This allows the gates of these two transistors to be controlled by the same voltage, here using a line connecting to the junction to the right of the corresponding main transistor, and have at most one of the transistors ON at any given point in the input cycle. In addition, the transistors in the main chain are n-type in FIG. **9**D, whereas the transistors of the main chain are p-type in FIG. **9**A. However, either of the embodiments of FIG. **9**A or FIG. **9**D could use n-type or p-type transistors in the main chain, with corresponding changes to the direction of connections as seen in the differences between FIG. **9**B and FIG. **9**C. FIGS. **9**C and **9**D don't show the additional transistor at the end of the rectifier that is shown as M_{n+1} in FIGS. **9**A and **9**B, but such an additional transistor may also be present in these figures. The additional transistor can be p-type or n-type.

[0078] To investigate the effectiveness of the adaptive blocks in reducing the leakage current, leakage current as a function of input power is plotted as shown in FIG. **11**A. The leakage current is simulated for the last transistor with a 1 MΩ load for different input power levels. As shown in FIG. **11**A, comparing the schemes i.e. hybrid, adaptive solid and adaptive diode-connected for power levels of 1 μW-100 μW and at an operating frequency of 915 MHz, the reverse leakage current is maximum for the hybrid scheme and increases with the input power. At an input power of 105 μW, the leakage current is 12 nA. The adaptive solid and the adaptive diode-connected scheme have an auxiliary transistor to control the reverse leakage current. At an input power of 1 μW, the auxiliary transistor does not have enough input power to turn ON and provide the required forward-compensation. Hence the leakage current is comparable with the hybrid scheme. At 1 μW (−30 dBm), the output transistor's leakage current is 6.96 nA for the adaptive solid scheme and 7.56 nA for the adaptive diode-connected scheme with a 1 MΩ load. As the input power increases, the leakage current for the adaptive scheme is drastically reduced as seen in FIG. **11**A. Also, the reverse leakage current for the adaptive schemes is relatively constant with increase in the input power. The leakage current also depends on the load resistance and increases with decrease in the load resistance. Another performance measuring parameter we have defined is the current transfer ratio which is the ratio of the forward-current to the reverse leakage current. FIG. **11**B shows the current transfer ratio as a function of input power. The current transfer ratio at an input power of 1 μW (−30 dBm) for the hybrid scheme is 270, for the adaptive solid scheme is 140 and for the adaptive diode-connected one is 108. The current transfer ratio for the adaptive solid scheme increases rapidly and outperforms the hybrid scheme from 2 μW (−27 dBm) while for the adaptive diode-connected one, the current transfer ratio intersects the hybrid curve at 11 μW. The current transfer ratio for the hybrid scheme initially increases with the input power and saturates to approximately 1500 at 100 μW of input power. The current transfer ratio for the adaptive solid scheme rapidly increases with the input power. At an input power of 90 μW, the current transfer ratio for the adaptive solid scheme is 9000 as shown in FIG. **11**B. The current transfer ratio for the adaptive diode-connected scheme is 4000 at 97 μW of input power. The current transfer ratio for the adaptive-solid scheme at an input power of 100 μW (−10 dBm) is 6 times while for the diode-connected one is 2.5 times better than the hybrid scheme.

[0079] The proposed adaptive scheme is effective in increasing the PCE with the addition of auxiliary adaptive blocks. The increase in the PCE with the addition of the adaptive auxiliary blocks for the adaptive diode-connected scheme is shown in FIG. **12**A. With the addition of the auxiliary block the maximum PCE increases to 12%. The auxiliary block is added for every alternate transistor. However, the additional power consumed by the auxiliary diode-connected transistor when the rectifying device in the main rectification chain is forward-biased prevents the scheme from achieving higher PCEs. Unlike the adaptive diode-connected scheme, the auxiliary adaptive block is added to all the transistors for the adaptive solid scheme. Except for the first and the last stage, all the transistors for the solid adaptive scheme have the adaptive blocks. The additional power consumption and the parasitic capacitance introduced by the auxiliary chain are much lower than the former circuit as the solid-connected scheme uses only one transistor of width 480 nm per adaptive block. Hence the PCE is relatively higher at extremely low power levels. As seen from FIG. **12**B, with the addition of adaptive blocks, the efficiency increases. FIG. **12**B shows the improvement in PCE of the rectifier with the addition of auxiliary block. The maximum PCE reaches to 33.5% when the number of adaptive blocks is 20, a figure much higher than the adaptive diode-connected scheme which has a maximum PCE of 12%. The PCE and the output voltage performance at a relatively higher power level 0 dBm to −20 dBm is much better compared with only the hybrid scheme.

[0080] Impedance Matching Technique

[0081] The overall PCE of the RF energy harvesting system can be improved by increasing the passive voltage amplification due to the matching network, which increases the overall voltage at the input of the rectifier. The rectifier is modeled as $R_{rec}-jX_{rec}$ where R_{rec} is the real part of the rectifier's impedance and X_{rec} is the imaginary part. An impedance matching circuit is designed to match it to 50Ω as shown in FIG. **13**.

[0082] The input capacitance is mainly associated with the parasitic capacitance of the transistors and the layout. As the number of stages increases, the input resistance decreases while the parasitic capacitance increases. Increase in the value of load current also decreases the input resistance. The major factor contributing to increase in load current is lower load resistance. Other factors affecting the input impedance is the aspect ratio (W/L) of the transistors, input power level. Increase in the aspect ratio, increases the parasitic capacitance whereas decreases the input resistance. At the output side, the rectifier can be modeled by a voltage source and an output resistance. Thus the non-linear characteristic of the rectifier circuit makes it difficult to analyze them. The input impedance of the rectifier can be assumed to be constant only when small signal input is applied. In this case, the transient signal is a large signal with a capacitive component at the

input causing a phase difference component ϕ to appear. The derivation in appendix though considers the reactive impedance still assumes the linear VI relationship. In real case, the VI relationship is non-linear and the input resistance is to be found using CAD tools.

[0083] Experimental Results—Hybrid Scheme

[0084] Three rectifiers, named as "efficiency", "voltage" and "1-stage PMOS doubler" are designed and fabricated in a 0.13 μm 8-metal CMOS process. The active die areas for efficiency circuit, voltage circuit and the 1-stage PMOS doubler test circuit are 230 μm×810 μm, 230 μm×1050 μm and 160 μm×70 μm respectively. The chip is wire-bonded onto PCB board with FR4 substrate and tested with Agilent MXG-N5181 signal generator at a frequency of 915 MHz using a single-tone sinusoidal signal. The receiver power is calculated by finding the average power at the input of the rectifier. The performance of the designed efficiency and voltage circuit is measured for a range of input power levels.

[0085] Output DC voltage was measured for different peak-to-peak input voltages. For a 1 MΩ load, an input voltage of 170 mV results in 2.4 V and 2.8 V for efficiency and voltage circuit, respectively. The voltage multiplication ratio (VMR) which is the ratio of DC voltage to the peak-to-peak input voltage is 14 and 17 for efficiency and voltage circuit respectively. A 220 mV signal results in 3.1 V for efficiency circuit and 4.0 V for voltage circuit. Similarly for a 5 MΩ load, an output of 2.7 V (VMR=16) for efficiency circuit and 3.0 V (VMR=18) for voltage circuit was measured at an input peak-to-peak voltage of 170 mV. Thus, voltage circuit which has a higher level of compensation than efficiency circuit has a lower input voltage requirement.

[0086] Harvested power was measured for different received powers. From the results, it was observed that at low power-level, the harvested power has a higher dependence on load current. For a 1 MΩ load at power levels greater than −30 dBm, the rate of decay in the harvested power curve is higher than the 5 MΩ load. The roll-off in the harvested power for a 1 MΩ load starts at about −20 dBm while the roll-off point for a 5 MΩ load is approximately −30 dBm. Even for voltage circuit, the rate of decay in the harvested power curve is greater for a 1 MΩ load compared to a 5 MΩ load. A lower load value has a higher current requirement. The performance of both the circuits in terms of roll-off is similar for the same load value. The designed efficiency and voltage circuit outperforms the circuit in Papotto et al. especially at low power levels. The efficiency circuit delivers an output power of 4.7 μW at an input power of −16.8 dBm (20.9 μW) when loaded by 1 MΩ. With a 5 MΩ load, the output power is 1 μW for an input power of −17.5 dBm (17.7 μW). An output power of 3.4 μW at an input power of −14.8 dBm (33.1 μW) for a 1 MΩ load is supplied by voltage circuit. A graph of the measurements was found to be in close agreement with the simulation results.

[0087] Power efficiency was measured for different received power levels. The measured and the simulated power conversion efficiency for efficiency and voltage circuit for different load resistance values are further compared. The efficiency comparison is done while de-embedding the input reflections in Papotto et al. The output DC voltage was also measured for the efficiency and voltage circuits for different load resistance values. The PCE is optimized for low power levels. When loaded by 1 MΩ, efficiency circuit attains a maximum measured PCE of 22.6% at −16.8 dBm (20.9 μW) while delivering 2.2 V to the output. A maximum measured PCE of 21.6% is obtained by efficiency circuit while producing an output voltage of 1.1 V at an input power of −26.5 dBm (2.23 μW) for a 5 MΩ load. At an input power level of −14.8 dBm (33.1 μW), voltage circuit achieves a maximum measured PCE of 10.2% for a 1 MΩ load while delivering 1.8 V. Due to a lower load current requirement for a 5 MΩ load, the output voltage is higher compared to a 1 MΩ load. At an input power of −22.5 dBm (5.6 μW), voltage circuit has a measured output DC voltage of 1 V while efficiency circuit has a measured output DC voltage of 1.8 V at −24 dBm (4 μW) for a 5 MΩ load.

[0088] Experimental Results—Adaptive Scheme

[0089] Three RF-DC power converters named as "adaptive solid," "adaptive diode-connected" and the "hybrid" circuits were designed and fabricated side by side in a 0.13 μm metal CMOS process with eight layers of metallization. The active die areas for adaptive solid and adaptive diode-connected is 0.25 mm^2 and hybrid circuit is 0.15 mm^2. The chip is wire-bonded onto a 2-layer FR-4 PCB board and tested with Agilent MXG-N5181 signal generator using frequency modulated continuous signal in the 902-928 MHz industrial, scientific and medical (ISM) band. An off-chip L-section impedance matching network is implemented on the PCB to convert the RF-DC power converter's input impedance to 50Ω. The output DC voltage was obtained with an oscilloscope or a digital multimeter. The measured and the simulated PCE for the adaptive and the hybrid scheme were compared for a load resistance of 1 MΩ at different input power levels. The output DC voltage was measured for the adaptive and the hybrid scheme for a load resistance of 1 MΩ. The simulation is performed at a frequency of 915 MHz which is the center frequency for the 902-928 MHz ISM band. The adaptive RF-DC power converters are designed to provide high PCE and a large output DC voltage for input power levels of 1 μW-100 μW (−30 dBm to −10 dBm). At larger input power, even with lower PCE the available output power is large hence designing for high input power levels is not so crucial. The adaptive solid scheme attains a maximum PCE of 32% at an input power of 32 μW (−15 dBm) with an output DC voltage of 3.2 V for a 1 MΩ load. For the input power of 32 μW and 1 MΩ load, the hybrid scheme has a PCE of 18% and delivers 2.6 V to the output. The adaptive diode-connected scheme has a maximum PCE of 11.3% at an input power of 118 μW while delivering 3.7 V to the output. The additional power consumed by the auxiliary diode-connected transistor when the rectifying device in the main rectification chain is forward-biased prevents the adaptive diode-connected scheme from achieving higher PCEs. The PCE was measured for different input power for the adaptive solid scheme at different load resistances. The output DC voltage for the adaptive solid scheme was also measured as a function of input power for different load resistances. As the load resistance decreases, the peak conversion efficiency curve shifts towards similar efficiencies at higher input power. The maximum measured PCE is 33.4% for a load resistance of 500 kΩ load at an input power of 83 μW. The PCE for a 500 kΩ load is larger than a 1 MΩ load for input power levels greater than 50 μW (−13 dBm). The peak power conversion efficiency curve is a function of the load resistance and can provide peak efficiency at a much lower power levels for larger load resistances. With decrease in load resistance, the circuit provides a smaller output voltage than with the high load resistance due to the low load current requirement at high load resistances. The hybrid scheme provides a larger output voltage compared

to the adaptive schemes for input power levels lesser than 15 μW. The adaptive scheme outperforms the hybrid scheme once the power-up threshold-requirement is met. A DC output voltage of 3.2 V is obtained at an input power of 64 μW (−12 dBm) for a 500 kΩ load.

[0090] The harvested power was measured as a function of input power for the adaptive and the hybrid scheme. When loaded by 1 MΩ, an output power of 10 μW is harvested with an input power of 250 μW (−6 dBm) for the hybrid scheme while the adaptive solid scheme harvests 10 μW with only 30 μW (−15.3 dBm) of input power. With a load resistance of 500 kΩ, 10 μW of output power is harvested at an input power of 42 μW (−13.8 dBm). An output power of 20 μW is harvested at an input power of 64 μW (−12 dBm) for a 500 kΩ load using adaptive solid scheme. For a 1 MΩ load, at larger input power, the PCE degrades much more rapidly compared to a 500 kΩ load. For a 1 MΩ load, 20 μW of power is harvested by the adaptive solid scheme at 164 μW (−7.9 dBm). Even with an input power of few milliwatts, the hybrid scheme is not effective in harvesting 20 μW of output power.

[0091] The adaptive scheme is highly effective when the input power is above 10 μW (−20 dBm) and a large output voltage (more than 1.5 V) is desired. The performance of the adaptive solid scheme is similar to the hybrid scheme for power levels of 1-10 μW (−30 dBm to −20 dBm). The sensitivity of the RF-DC power converter for obtaining an output voltage of 1 V with a 1 MΩ load for the adaptive solid scheme is 8.9 μW (−20.5 dBm). The sensitivity of the circuit using the hybrid scheme is 6.9 μW (−21.6 dBm). The adaptive diode-connected scheme gives similar performance as the adaptive solid scheme at input power levels greater than 100 μW (−10 dBm). For low power applications, the adaptive solid scheme should be preferred over the adaptive diode-connected scheme.

[0092] The forgoing description pertains to circuitry using MOSFET enhancement-mode transistors. Nothing in the description should be taken to exclude using other types of transistors with corresponding changes to the circuitry that would be obvious to a person skilled in the art.

[0093] Immaterial modifications may be made to the embodiments described here without departing from what is covered by the claims.

[0094] In the claims, the word “comprising” is used in its inclusive sense and does not exclude other elements being present. The indefinite articles “a” and “an” before a claim feature do not exclude more than one of the feature being present. Each one of the individual features described here may be used in one or more embodiments and is not, by virtue only of being described here, to be construed as essential to all embodiments as defined by the claims.

APPENDIX

[0095] In section II, the average input power was suggested consisting of real and imaginary parts.

$$V = V_{in}\sin\omega t,\ I = I_{in}(\sin\omega t - \phi)$$

$$P_{mean} = \frac{1}{T_2 - T_1}\int_{T_1}^{T_2} V_{in}\sin\omega t \cdot I_{in}(\sin\omega t - \phi)dt$$

$$Z_{in} = \frac{V_{in}^2}{2P_{mean}}\cdot\cos\phi + \frac{V_{in}^2}{4P_{mean}}\cdot\frac{\sin[2\omega(T_2 - T_1) - \phi]}{\omega(T_2 - T_1)}$$

[0096] Z_{in} consists of real and imaginary component. Equating the imaginary component to zero by considering the phase difference ϕ=0.

$$R_{in} = \frac{V_{in}^2}{2P_{mean}},\ C_{in} = \frac{4P_{mean}(T_2 - T_1)}{V_{in}^2\sin[2\omega(T_2 - T_1) - \phi]}$$

1. A power conversion circuit comprising:

a first input line and a second input line, the first and second input lines configured to receive an alternating voltage differential between the first and second input lines;

a multi-stage rectifier comprising transistors arranged in series, each transistor having a gate, a source and a drain, adjacent transistors of the series being connected so that for adjacent p-type transistors the drain of the left p-type transistor is connected to the right adjacent source of the right p-type transistor and source of the right p-type transistor is connected to the left adjacent drain of the left p-type transistor, for adjacent n-type transistors the source of the left n-type transistor is connected to the right adjacent drain of the right n-type transistor and drain of the right n-type transistor is connected to the left adjacent source of the left n-type transistor, for a p-type transistor adjacent to an n-type transistor the source of the right p-type transistor is connected to the source of the left adjacent n-type transistor and drain of the left p-type transistor is connected to the drain of the right adjacent n-type transistor to form a junction, each junction being connected to one of the first input line and the second input line via a capacitor, with adjacent junctions having one junction of the adjacent junctions connected to the first input line and the other junction of the adjacent junctions connected to the second input line;

the gate of each transistor of the multi-stage rectifier being connected to a respective junction that is not a junction formed by the connection of that transistor to an adjacent transistor but a junction in the previous stage for the p-type transistor or later stage for the n-type transistor, at least one of the transistor in the multi-stage rectifier being p-type and at least one being n-type.

2. The power conversion circuit of claim **1** further comprising an auxiliary chain of p-type transistors, each auxiliary transistor having a gate, a source and a drain, each transistor of the auxiliary chain being connected to a p-type transistor of the multi-stage rectifier in the main chain, so that the gate of the respective auxiliary transistor is connected to the source of the respective transistor in the main chain, the source of the respective auxiliary transistor is connected to the gate of the transistor in the main chain and also connected to the previous stage junction of the main chain which is N transistors away from the respective transistor, and the drain of the respective auxiliary transistor is connected to the drain of the respective transistor or to the junction of the later stage transistor in the main chain.

3. The power conversion circuit of claim **1** further comprising an auxiliary chain of n-type transistors, each auxiliary transistor having a gate, a source and a drain, each transistor of the auxiliary chain being connected to an n-type transistor of the multi-stage rectifier in the main chain, so that the gate of the respective auxiliary transistor is connected to the source of the respective transistor in the main chain, the source of the respective auxiliary transistor is connected to

the gate of the transistor in the main chain and also connected to the later stage junction of the main chain which is N transistors away from the respective transistor, and the drain of the respective auxiliary transistor is connected to the drain of the respective transistor or to the junction of the previous stage transistor in the main chain.

4. An auxiliary chain of transistors, each auxiliary transistor having a gate, a source and a drain, each transistor of the auxiliary chain being connected to a respective transistor of a main chain of a multi-stage rectifier in the main chain, so that the gate of the respective auxiliary transistor is connected to the source of the respective transistor in the main chain, the source of the respective auxiliary transistor is connected to the gate of the transistor in the main chain and also connected to the later stage junction of the main chain which is N transistors away from the respective transistor in the case that the respective transistor is n-type, or to the earlier stage junction of the main chain which is N transistors away from the respective transistor in the case that the respective transistor is p-type, and the drain of the respective auxiliary transistor is connected to the drain of the respective transistor or to the junction of a previous stage transistor in the main chain, in the case that the respective transistor is n-type, or to the junction of a later stage transistor in the main chain, in the case that the respective transistor is p-type.

5. The power conversion circuit of claim **4** in which the transistors of the main chain and auxiliary chain are n-type and further comprising a p-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of later stages, such that the gate of the additional p-type auxiliary transistor is connected to the gate of the n-type auxiliary transistor and the source of the n-type and p-type auxiliary transistors are connected, and the drain of the p-type auxiliary transistors is connected to junction of the main chain which is at 'N' later stages from the respective transistor.

6. The power conversion circuit of claim **4** in which the transistors of the main chain and auxiliary chain are p-type and further comprising an n-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of earlier stages, such that the gate of the additional n-type auxiliary transistor is connected to the gate of the p-type auxiliary transistor and the source of the n-type and p-type auxiliary transistors are connected, and the drain of the n-type auxiliary transistors is connected to junction of the main chain which is at 'N' earlier stages from the respective transistor.

7. The power conversion circuit of claim **2** further comprising a diode connected transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of previous stages which is N transistors away from the respective transistor.

8. The power conversion circuit of claim **3** further comprising a diode connected transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of later stages which is N transistors away from the respective transistor.

9. The power conversion circuit of claim **4** further comprising a diode connected p-type or n-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of later stages which is N transistors away from the respective transistor.

10. The power conversion circuit of claim **4** further comprising a diode connected p-type or n-type transistor on a line connecting the gate of each transistor in the main chain of the multistage rectifier to the junction of earlier stages which is N transistors away from the respective transistor.

11. The power conversion circuit of claim **1** further comprising an additional transistor connected in series with the multistage rectifier, the additional transistor having a gate, a source and a drain, the gate of the additional transistor being connected to the drain of the additional transistor.

12. The power conversion circuit of claim **1** in which the gate of each transistor in the main chain is connected to the junction of previous stages for p-type transistor and later stages for n-type transistor.

13. The power conversion circuit of claim **12** in which N of the transistors in the multistage rectifier arranged in series are n-type and all but N of the transistors in multistage rectifier arranged in series are p-type.

14. The power conversion circuit of claim **1** in which the second input line is grounded.

15. The power conversion circuit of claim **1** in which the body terminal of each p-type transistor is connected to the respective drain and the body terminal of each n-type transistor is either grounded or connected to the respective drain terminal.

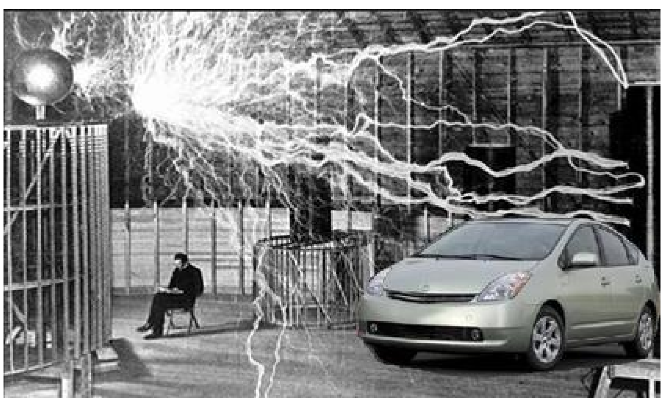
* * * * *

(/)

Apparently Apparel's
Alternative News

Nikola Tesla's Wireless Electric Automobile Explained (//www.apparentlyapparel.com/news/nikola-teslas-wireless-electric-automobile-explained)

5/5/2012 142 Comments (//www.apparentlyapparel.com/news/nikola-teslas-wireless-electric-automobile-explained#comments)



Compiled by Zach Royer (http://zachroyer.com)
Updated June 20, 2012 - See End of Article

It is safe to say that there isn't and will never be an energy crisis, under the premise of new or free energy. Energy is all around us. Energy is free for the taking. How you get free infinite energy is so simple.

Our Sun emits electromagnetic energy and that energy showers down on us throughout the whole 24 hours, and if a energy receiving device (an antenna) can easily be built to harness and use this power it will not require devices for storing energy as would be necessary with devices using wind, tide or sunlight.

In one hour, or 3600 seconds, our Sun produces 1.4 x 10^31 Joules of energy or 3.8 x 10^23 kilowatt-hours. It's been doing this for about 4.5 billion years and will continue to do this every second, of every minute, of every hour, of every day, of every year – for another 4.5 billion years.

That means free energy will be available to mankind for another 4.5 billion years.

Today, in 2012, we can remove every gasoline combustion engine and replace it with a zero emission electric motor. At the same time we can remove the gas tank, the fuel lines, the exhaust system, the water pump, radiator, and all emission control devices because an electric motor car doesn't need them. We didn't need them 81 years ago and we don't need them now.

Nikola Tesla proved in 1931 that it is possible to power our vehicles without a drop of fossil fuel. He removed the gasoline engine of a Pierce Arrow and replaced it with an electric motor and drove for hours, at speeds as high as 90 mph. Today, 81 years later, it is still possible to convert any gasoline engine vehicle into an all-electric vehicle and it will operate for hours – without having to stop and recharge. Not a drop of oil, gasoline, hydrogen fuel, natural gas or water. No combustion engine. No exhaust system. No pollution.


Modern Valve Amplifier

We don’t need them because electric motor cars don’t need a drop of gasoline or diesel. Because they don’t need or use a single drop of gasoline or diesel electric motor cars produce zero carbon (CO) emissions. No CO emissions means no smog and no contributing to global warming. No CO emissions also means the elimination of most respiratory diseases. That alone will save $billions in health care costs. The US wouldn’t need Obama’s unconstitutional Health Care Extortion Bill. Just 1 gasoline or diesel vehicle produces tons of carcinogenic (cancer causing) CO each year.

The fact that electric cars don’t need fuel tanks or fuel lines means the elimination of fuel leakage and fuel fires in an automobile accident. How many people have been burned alive, trapped inside their burning oil fuel vehicle? No amount of airbags are going to save you if your oil fuel tank or oil fuel line ruptures and ignites. Apart from the horrific consequences of driving around, strapped inside an oil fuel bomb, the fuel tank needs to be constantly filled up with very expensive ($4 to $5 a gallon) diesel or gasoline fuel. Can you afford to continue to pay $80 to $100 to fill up? How far can you go on $80 to $100 of oil fuel? Does it last you the week?

Electric cars have no rusting and pollution (CO) emitting exhaust manifolds, no catalytic converters, no O2 sensors, no mufflers and no tailpipes. How much does it cost you every year to replace those rusting oil fuel exhaust parts?

Electric motor vehicles have no radiators, no toxic radiator fluid, no coolant pump, no coolant lines and no radiator hoses. Electric motors don’t get as hot as oil fuel engines so they don’t need all those costly and bulky cooling system parts. That means if you drive an electric vehicle you won’t overheat and get stranded on the highway in rush hour traffic, during a heatwave.

You can run an electric vehicle indoors for hours or days and not kill (by CO asphyxiation) anyone. Try doing that with a oil fuel vehicle and you will no doubt send a lot of people to the hospital or to the morgue.

Whenever someone who owns a Big 3 (Government Motors, Ford and Chrysler) manufactured oil fuel vehicle brags to me that their new vehicle is environmentally friendly I always tell them that if you truly believe that, prove it by parking it in their garage, with the garage door closed, the engine running and them sitting in it.

We didn’t need combustion engines 81 years ago and we don’t need them now. Let’s make 2012 the year the World got off oil.

TELSA HAD SUPPORT - WHAT HAPPENED?

Supported by the Pierce-Arrow Co. and General Electric in 1931, Tesla took the gasoline engine from a new Pierce-Arrow and replaced it with an 80-horsepower alternating-current (AC) electric motor with no external power source. At a local radio supply shop he bought 12 vacuum tubes, some wires and assorted resistors, and assembled them in a circuit box 24 inches long, 12 inches wide and 6 inches high, with a pair of 3-inch rods sticking out. Getting into the car with the circuit box in the front seat beside him, he pushed the rods in, announced, “We now have power,” and proceeded to test drive the car for a full week, often at speeds of up to 90 mph. His car was never plugged into any electrical receptacle for a recharge. As it was an alternating-current motor and there were no batteries involved, where did the power come from?

Tesla used the collection of vacuum tubes (also called a valve amplifier), wires and assorted resistors to build a radio wave receiver/amplifier 24 inches long, 12 inches wide and 6 inches high, with a pair of 3-inch rods 1/4” in diameter sticking out. The pair of rods that Tesla pushed in were used to close (complete) the circuit – like an on/off switch. The rod ends were most likely the positive and negative leads (connections) between the car antenna and and the radio wave receiver/amplifier. By pushing them into the box containing the radio wave receiver/amplifier the connection was completed allowing the radio waves that were received from the air by the antenna to flow through the receiver/amplifier to the electric motor.

Tesla’s electric control box worked much the same way as an electric guitar amplifier. Like the electric guitar amplifier the signal generated by striking a cord (string) of a guitar would travel from the guitar through the wire connecting the guitar to the amplifier and into the amplifier where the barely audible tone would then be amplified.

An electric guitar without an amplifier is essential an air guitar until it is plugged into an amplifier. The amplifier amplifies the sound wave generated by striking the strings of the electric guitar. That is basically how Tesla was able to amplify and convert the invisible electromagnetic radiation called radio waves into electricity to power the AC motor in the 1931 Pierce-Arrow. The word electricity comes from the fact that current is nothing more than electrons moving along a conductor, like an antenna, that have been harnessed for energy. Tesla used an antenna (an electrical conductor) and an amplifier to harness and then amplify energy.

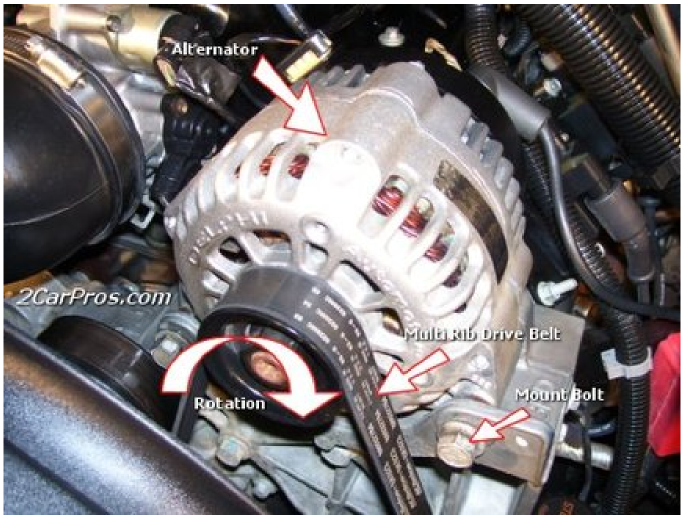
An amplifier’s job is to take a weak audio signal and boost it to generate a signal that is powerful enough to drive a speaker, or in the above case, an electric motor. Today the component at the heart of most amplifiers is the transistor. Transistors have replaced Tesla’s vacuum tube (also called valve amplifier).

A transistor is a semiconductor device used to amplify and switch electronic signals and power. It is composed of a semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor’s terminals changes the current flowing through another pair of terminals. Because the controlled (output)

power can be higher than the controlling (input) power, a transistor can amplify a signal.

So today you can amplify a weak audio signal with transistors instead of valve amplifiers.

(/)



In case you didn't notice, there is no mention that Tesla removed the alternator of the Pierce Arrow. It just stated that the gas combustion engine was removed and replaced with an 80-horsepower AC electric motor. Why is this significant? How was he able to drive for hours, at speeds as high as 90 mph without stopping to recharge? Because of the alternator. Alternators are used in all gas combustion engine automobiles to charge the battery and to power the electrical system when its engine is running. Even the Ford Model T automobiles from 1919 to 1927 had a 12 volt negative ground Delco style alternator – http://www.snydersantiqueauto.com/uploads/T5119BD-4220-xl.jpg (http://www.snydersantiqueauto.com/uploads/T5119BD-4220-xl.jpg).

It is entirely plausible that Tesla made use of the alternator to continually recharge the Pierce Arrow's single 12 volt automotive battery and help supply sufficient power to the electric motor.

Alternators do not produce a set voltage. The faster the rotor in the alternator spins, the more the voltage increases. However, your vehicle's electrical system is unable to operate if the voltage fluctuates constantly, so voltage is regulated using a voltage regulator that for most vehicles is set to 12 volts. Ford's Model T had voltage regulators http://www.funprojects.com/products/5055r.cfm (http://www.funprojects.com/products/5055r.cfm). Until the 1970s, automobiles used DC dynamo generators – http://www.ccw-tools.com/uploads/images_products_large/36780.jpg (http://www.ccw-tools.com/uploads/images_products_large/36780.jpg) – with commutators. With the availability of affordable silicon diode rectifiers, alternators were used instead. You can buy a 10mA 20kV High Voltage Diode HV Rectifier for a Tesla Ham for as little as $0.72 http://hvstuff.com/10ma-20kv-high-voltage-diode-hv-rectifier-tesla-ham (http://hvstuff.com/10ma-20kv-high-voltage-diode-hv-rectifier-tesla-ham)

(/)

Ignition coils already existed back in the 1930s too. An ignition coil (also called a spark coil) is an induction coil in an automobile's ignition system which transforms the battery's low voltage to the thousands of volts (around 10 – 20kV) needed to create an electric spark in the spark plugs to ignite the fuel. It is also entirely plausible that Tesla used the Pierce Arrow's ignition coil to transform the antenna receiver's low voltage to hundreds of volts needed to power the electric motor. AC electric motors requires more than 12 volts of AC current. It doesn't need 10-20,000 volts. So all Tesla needed to do is use the Pierce Arrow's ignition coil to transform the very weak signal captured by the antenna (an electrical device which converts electric currents into radio waves, and vice versa.) into a constant 120 volts or the required voltage needed to power the 80-horsepower AC electric motor.

Electricians know what I am talking about and can easily replicate Tesla's achievement. Tesla more than likely made use of the Pierce Arrow's alternator and ignition coil and made it possible to drive for hours, at speeds as high as 90 mph.

TESLA AND HIS MYSTERIOUS VACUUM TUBES

Why did Tesla use so many vacuum tubes? He bought 12 vacuum tubes.

In electronics, the Darlington transistor (often called a Darlington pair) is a compound structure consisting of two bipolar transistors connected in such a way that the current amplified by the first transistor is amplified further by the second one. This configuration gives a much higher current gain than each transistor taken separately.

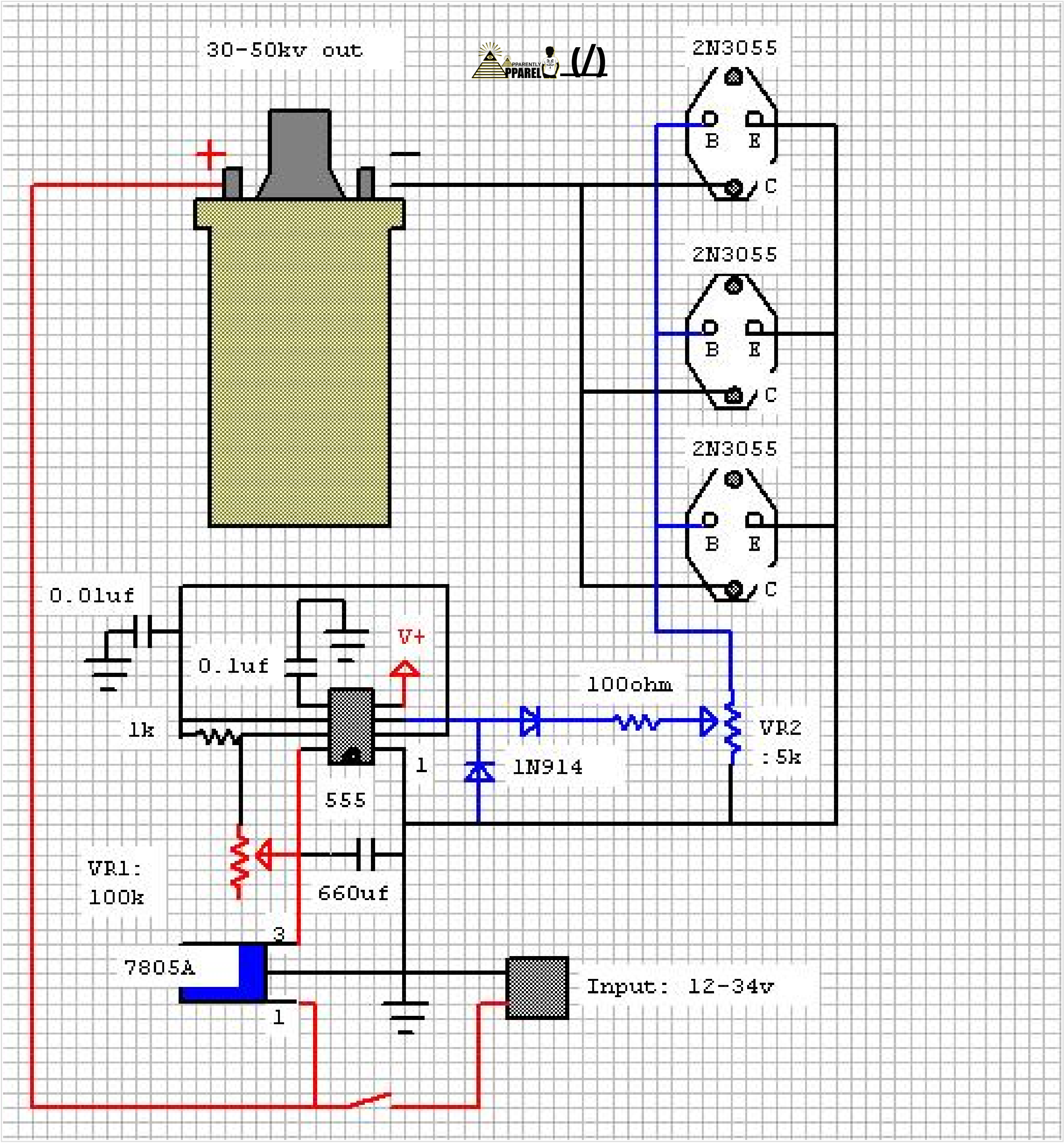
The Darlington Pair is renowned as a method for obtaining a very high level of current gain, using just two transistors. It is able to provide levels of gain that are not possible using single transistors on their own. The gain of the Darlington transistor pair is that gain of the two individual transistors multiplied together. This gives the Darlington pair a very high current gain, such as 10000, so that only a tiny base current is required to make the pair switch on.

A transistor is a semiconductor device used to amplify and switch electronic signals and power. A valve amplifier or tube amplifier is a type of electronic amplifier that makes use of vacuum tubes to increase the amplitude of a signal. Therefore, transistors and semiconductor devices replaced the vacuum tube to amplify a weak signal. So essentially, Tesla used 12 vacuum tubes paired up to obtain a very high level of current gain.

But the Darlington pair was only discovered decades later (in 1953). Or was it? Tesla used so many vacuum tubes to create a push-pull signal amplifier. A push-pull signal amp requires at least two tubes (a pair of tubes is the same as a pair of transistors or Darlington Pair) to operate, but can have more connected in parallel with each side, resulting in an amp with four, six, eight output or even 12 tubes for much higher power amplification. When the tubes are connected in parallel it is called a "parallel push-pull" amp.

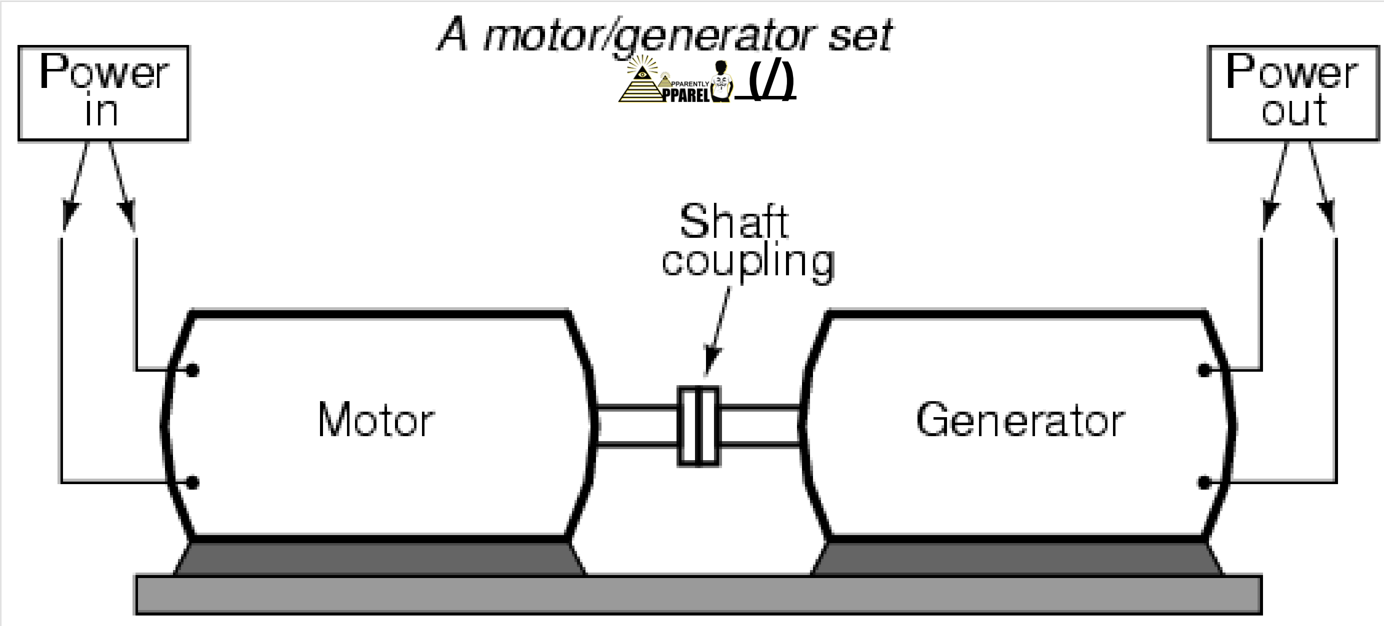
In a push pull signal amp the power supply is connected to the center-tap of the transformer (An Ignition coil is like and can be used as a high voltage transformer) and a tube is connected to both the upper and lower end of the center-tapped primary. This allows the tubes to conduct on alternate cycles (Alternating current or AC) of the input waveform.

So in short – Tesla connected the antenna (an electrical device which converts electric radio waves into current – i.e. an infinitely free power supply) to the center-tap of the ignition coil of the Pierce Arrow. 12 vacuum tubes were then wired (connected) together in parallel and connected to the ignition coil. In this circuit, Tesla amplified the very weak radio wave signal and produced a very high voltage output. Enough to power the 80 HP AC electric motor for a full week, often at speeds of up to 90 mph.

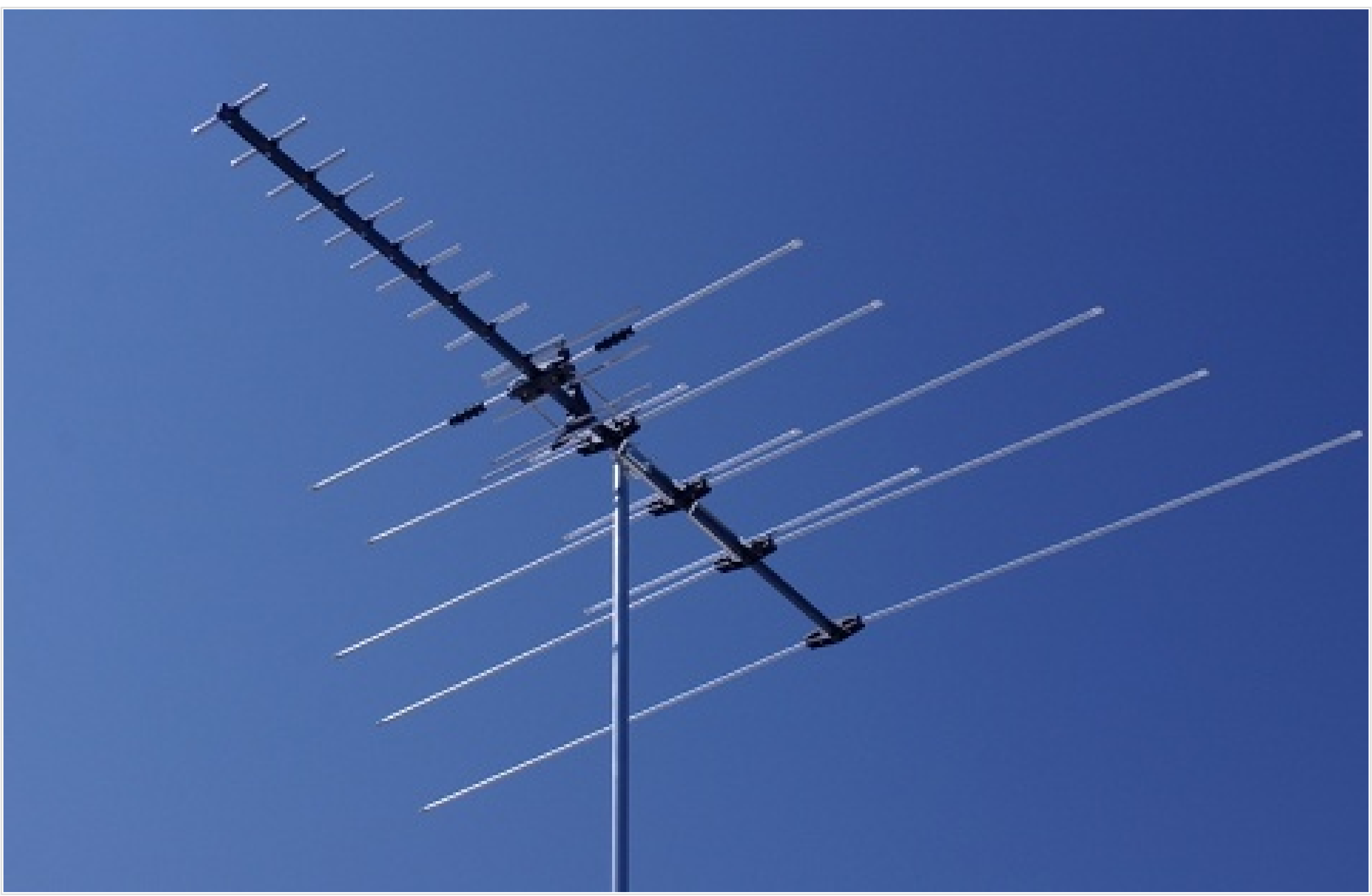


If you can power an electric motor using a few electronic devices and free radiant energy and power a very heavy automobile couldn't you also use the same technology to power your home? The answer is yes.

If you can erect an antenna on a car and connect it to an ignition coil and transistors and amplify the antenna received weak signal into enough electrical energy to power a car you can also do the same and power your home.



Mass produced gas powered generators can be stripped down and used as a Tesla free radiant energy receiver and electrical power generator. Remove the small gas combustion engine and replace it with a small electric motor. Connect the shaft of the small electric motor to the shaft of the rotor of the electric generator. Erect a TV or CB antenna on the roof of your house and connect (wire) it to a circuit box like the one Tesla made. Wire this circuit box to the electric motor and complete the circuit.



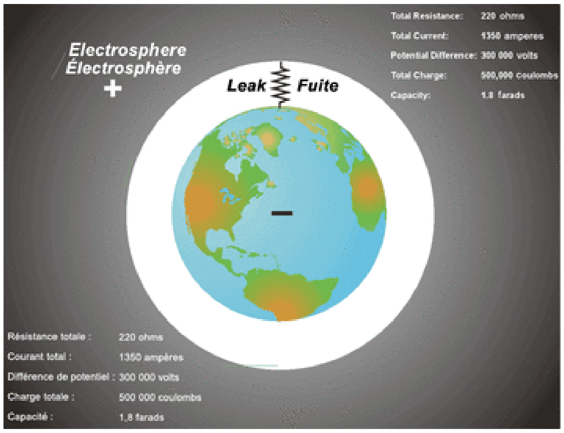
The key to unlimited free home energy is erecting the antenna above head height. Why? Physicists have determined that the earth has a negative charge which amounts to 400,000 columbs, yet six feet above the ground (above head height) the air is charged with more than 200 volts positive in respect to the ground (http://www.only1egg-productions.org/AltSci/SOE/Sea_Of_Energy_5thEd_Chapter7.htm). Your electrical outlets and home appliances are charged with 120 volts positive. An antenna is a free energy receiver. It receives free radiant energy and converts it into electric current. So an antenna erected on the roof of a house will tap into and immediately start receiving this free and infinite supply of 200 volts positive energy.

After all, an electric generator is a device that converts mechanical energy obtained from an external source into electrical energy as the output. The rotating rotor (mechanical) generates a moving magnetic field around the stator, which induces a voltage difference between the windings of the stator. This produces the alternating current (AC) output of the generator. So

what Tesla did with a gas combustion automobile can be done with a gas combustion electrical power generator.

Tesla proved that you can drive a car for a full week using no fuel whatsoever. Tesla also proved that you can also power your home, using no fuel whatsoever.

Bottom line is, you will never need to buy fuel for you car or home again.



Everything on Earth is energy. Even the Earth and its atmosphere is energy. According Dr. Thomas Henry even empty space itself not only contains prodigious quantities of energy, but in fact was prodigious quantities of energy. Today we now know that one cubic centimeter of pure vacuum contains enough energy to condense into 10 to the 80th power to 10 to 120th power grams of matter! Thus the major part of Moray's thesis that vacuum itself contains unlimited energy is vindicated today. In this sense empty space is like a gigantic, restless ocean of energy.

Earth is always referred to as ground when explaining electrical circuitry. Electrical current flows to ground or earth. The Earth – the ground we stand on, walk on, sleep on , play. run on, drive on and build on is negative electrically charged and acts as a spherical capacitor. The Earth has a net negative charge of about a million coulombs, while an equal and positive charge resides in the atmosphere – or at least that is what Canada's Department of Natural Resources states on their website – [http://cfs.nrcan.gc.ca/pages/160 (http://cfs.nrcan.gc.ca/pages/160)].

Natural Resources Canada goes on to state:

"*The electrical resistivity of the atmosphere decreases with height to an altitude of about 48 kilometres (km), where the resistivity becomes more-or-less constant. This region is known as the electrosphere. There is about a 300 000 volt (V) potential difference between the Earth's surface and the electrosphere, which gives an average electric field strength of about 6 V/meter (m) throughout the atmosphere. Near the surface, the fine-weather electric field strength is about 100 V/m.*."

The Canadian government is telling us that every meter of the electrosphere has a 6 V positive charge and near the surface, every meter of the atmosphere we breathe has a 100 Volt positive charge.

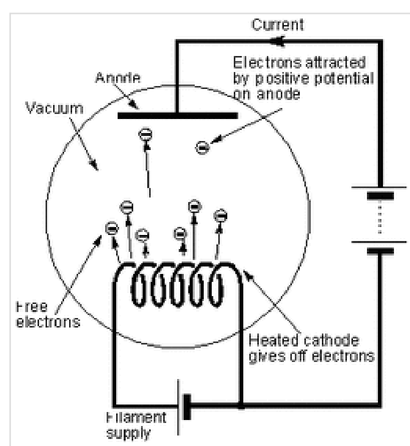
Wikipedia also states that Earth's atmosphere is electrically charged. They disclose this with this statement – "The measurements of atmospheric electricity can be seen as measurements of difference of potential between a point of the Earth's surface, and a point somewhere in the air above it. The atmosphere in different regions is often found to be at different local potentials, which differ from that of the earth sometimes even by as much as 3000 Volts within 100 feet (30 m). The electrostatic field and the difference of potential of the earth field according to investigations, is in summer about 60 to 100 volts and in winter 300 to 500 volts per meter of difference in height, a simple calculation gives the result that when such a collector is arranged for example on the ground, and a second one is mounted vertically over it at a distance of 2000 meters and both are connected by a conducting cable, there is a difference in potential in summer of about 2,000,000 volts and in winter even of 6,000,000 volts and more." http://en.wikipedia.org/wiki/Atmospheric_electricity (http://en.wikipedia.org/wiki/Atmospheric_electricity)

What both Wikipedia and the Canadian government are stating is exactly what Nikola Tesla and Dr. Thomas Henry Moray stated 80 years ago and tried to educate the World that we are surrounded by a sea of energy. We need only know how to tap into it to power everything we use. Moray even developed and successfully demonstrated a device that harnessed this free energy and powered 35 100-watt lamps and a 1200-watt iron simultaneously.

Moray's device used twenty-nine stages of his special detector valves. His device was based on the discovery of a mixture that would act as a one-way gate for the high frequency oscillations of space, so that the energy could go through the material more readily in one direction than another. Electrons could flow in each valve, but was prevented from flowing back out.

What would only allow electrons to flow in one direction? A vacuum tube diode. now rarely used except in some high-power technologies and by enthusiasts, is a vacuum tube with two electrodes, a plate (anode) and cathode.

The most common function of a diode is to allow an electric current to pass in one direction (called the diode's forward direction), while blocking current in the opposite direction (the reverse direction). Thus, the diode can be thought of as an electronic version of a check valve. This unidirectional behavior is called rectification, and is used to convert alternating current to direct current, including extraction of modulation from radio signals in radio receivers—these diodes are forms of rectifiers.



I don't know about you but it would appear that Moray used vacuum tube diode as his special detector valves to tap into and harness the free electrical energy that surrounds us – 100 volts/meter of free energy.

Sources:

1. **Tesla's Colorado Spring Notes (/uploads/5/3/5/6/5356442/_337910-nikola-tesla-colorado-springs-notes.pdf)**
2. **Henry Moray's Notes (/uploads/5/3/5/6/5356442/morayfreeenergy.pdf)**
3. **Free Electricity from the Sky PDF (/uploads/5/3/5/6/5356442/______371-free-electricity-from-the-sky.pdf)**
4. **The Practical Antenna Handbook, Fourth Edition (/uploads/5/3/5/6/5356442/_____practical_antenna_handbook_fourth_edition_carr.pdf)**

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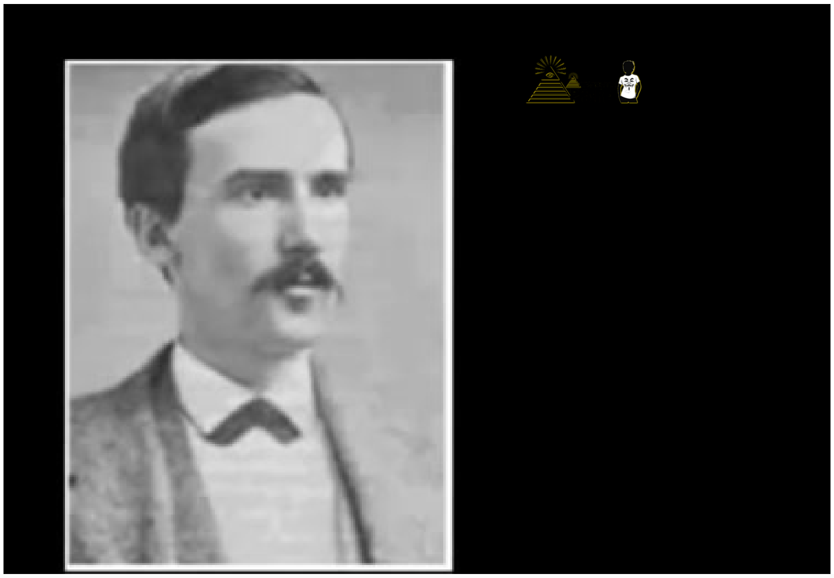

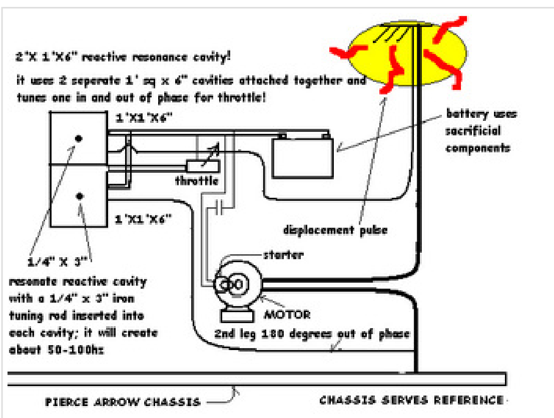

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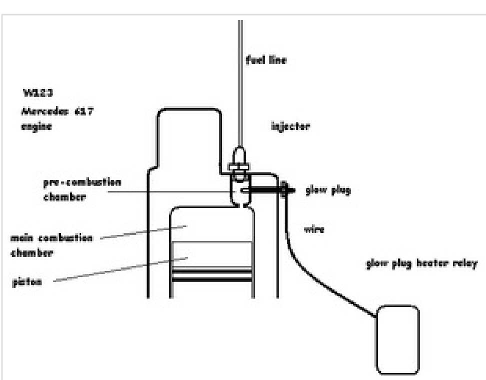
Click Image To Enlarge

UPDATED June 20, 2012 13:22 HAST

Diagram & text submitted by viewer *masthead*. Many thanks from AA!

"This is a crude block diagram of the Tesla device....it's all I can remember these days so it is lacking important details that can be duplicated by an enterprising garage inventor. The main thing is that Tesla used a transmitter and not a receiver...his transmitter resembled a ***Super Heterodyne*** *system; but, the difference is that each 6 tube assembly of the 12 tube total system [if that is really accurate] is for each 12"12"x6" reactive cavity [2'x12"x6" total cabinet dimension making two 12"x12"x6" enclosures that need a tuning rod that is 3" tall to tune a 6" deep cavity!] and the propose of them is to provide a 50-100hz boosted occolations [from the battery power through the cold tubes] into the mast antenna inductive coil. The invitation excitation comes from the frame reference which is biased to the other 2 phase motor tap. NOTE: the motor has to be started via a standard electric automotive engine starter, that initially props over the system. all of these functions should be easily reproduced by frequency generators and amplifiers.*

When each system is in phase the motor will spool up until it explodes or melts down. controlling it [taking them out of phase of each other] is to take one system out of phase via a variable resistor [making it the throttle]. the beauty of this system is that it will alway need constant throttle corrections; but, used in automotive applications, that is done by automatically, unconsciously, the operator/driver.



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The other issue is to harmonic electronically/acoustically refract diesel fuel before combustion; and, I think that is already being done by some automotive companies. I inspected a VW TGI diesel set of glow plugs and they were worn substantially in just a short amount of time! The per-combustion chamber, in a Mercedes 300D, should be replicated by a titanium version to amplify the effects of harmonics on the fuel; and, the induced frequency has to be matched to the harmonics of the fuel. The Mercedes 300d [1983-1985] is perfect for experimentation as the glow plug circuitry is uniquely suited for this application. Shown is the combustion chamber. The drawing amalgamates the Tesla transmitter banks [tubes etc] with the reactive cavities, to save time & explanation, they can be reproduced with frequency

generators & amplifiers so it doesn't matter about the missing details. The diesel application can use an OX sensor along with a FG [frequency generator] and amplifier [spliced into the conductor after the glow plug relay and ahead of the glow plugs] to sweep frequencies and amplification to get it combustion efficiency dialed in....
also, Stanley Meyers must be using 2.4 gHz [water molecule's splitting frequency?] to cut power & time to split the hho from water...

*It is clear that **the law of conservation of energy** is a total hoax! When you read about Joseph Keely and what he did in the 1850's [Tesla was a huge fan of his and was in a photograph with him...look up **Keely net**] it is clear that we have been lied to about everything. - **masthead** (Editor's note - This info was deemed necessary to update the article with, thanks again masthead.)*

CORRECTIONS:
We changed CO2 to CO as we were talking about Carbon and not Carbon Dioxide. Thank you for the comments.

We do not claim to be Tesla experts, nor do we claim the information in this article is entirely true or fact.

142 Comments (//www.apparentlyapparel.com/news/nikola-teslas-wireless-electric-automobile-explained#comments)

Trailer Parts (http://trttrailersales.com/) 5/9/2012 06:35:55 pm

It is so important to protect the car from electricity on the road and your method of saving it is so interesting and useful.

REPLY

vinod kumar 4/17/2013 07:18:46 am

iam car

REPLY

Me 2/2/2016 09:45:01 am

The Tesla car story is a hoax from the '60's. Don't be so gullible! Stick to the facts.

REPLY

oil change (http://countrytowntire.wordjack.com/business/warning-signs-brake-replacement-may-be-necessary) 5/26/2012 02:10:48 am

Wonderful!! this is really one of the most beneficial blogs I've ever browsed on this subject.I am very glad to read such a great blog and thank you for sharing this good info with us.

REPLY

J.H. Venski 6/16/2012 08:50:59 am

The following statement in your blog is incorrect!

"Even the Ford Model T automobiles from 1919 to 1927 had a 12 volt negative ground Delco style alternator"

Only those Model T Fords from 1919 through 1927 that were built with the optional, extra cost, electric starting system, came from the factory with a storage battery - which was ONLY 6 volts. They did not use an alternator for recharging the battery, but instead came with an adjustable, three brush, gear driven generator with a magnetic cutout switch.

REPLY

dave reece 7/22/2012 02:42:56 am

I noticed that too jh your exactly right. I still wanna believe tesla knew how to harness that energy.

APPARENTLY APPAREL (/)

REPLY

Joshua 6/16/2012 09:09:37 am

Build one and I'll believe you've figured it out. Since you listed CO2 as a carcinogen near the beginning, I also doubt that you know diddly about power, either. But I'm willing to accept that you do know something AFTER you've built a device that does what Tesla's did.

REPLY

Charles Stewart 6/22/2012 04:14:45 am

He listed CO, carbon MONoxide, not CO2, carbon dioxide. Big difference!

REPLY

John Thomas 6/27/2012 06:39:44 pm

if you doubt this you need to visit the website of "A. Aviso - Philippine inventor." He has been successful in rebuilding Tesla's invention and put it in a frame car to drive around the Philippines himself, something which has been seen not only by his neighbors but the Philippine government and local universities

REPLY

loL 7/10/2014 11:44:57 am

Ahaha, everyone knows that Aviso is full of something, he is the technological equivalent of Philippine witch doctors. look at one of his other "inventions" and tell me if this guy is not a fake:

https://www.youtube.com/watch?v=Q_JVntFlDos

"According to its maker Ismael Aviso, this pendant has great properties:
- Vitalizes the immune and endocrine system;
- Enhances cellular nutrition and detoxification;
- Protects the DNA;
- Helps retard the ageing process;
- Protects the body from electromagnetic radiations;
- Helps the body fight against cancer;
- Enhances blood circulation;
- Increases mental concentration;
- Reduces inflammation;
- Boosts vitality"

Julian Davies 5/22/2015 01:51:56 pm

Hey Joshua, They said there would never be a viable electric car because they would never have the range. So why do we have so many now that have the range and are viable. In other words, never say never, he may have known something you do not. Nothing is impossible, just wait and see.

REPLY

Carlos 6/16/2012 09:29:50 am

You r so full of s??t transistors, vac tubes r not above unity and require a power source.

REPLY

chris (http://iservesocial.com) 6/16/2012 10:22:31 am

Carlos, he explains pretty clearly that the earth and the atmosphere are the power source. You think there is no energy in lightning?

REPLY

Nick 10/23/2012 07:49:07 pm

But the article talks about amplifiers as if they somehow provide power/energy input from nowhere.... They themselves need power to amplify the signal. They do not _add_ to the signal energy. They modulate exterior power in response to the weak input signal. They are just like an electric "gate valve" turning mains water on and off in response to a small signal to a control.

thomas 7/8/2014 05:10:49 am

but if the concept of extracting energy from the atmosphere by simply connecting earth with a higher point would work then there wouldnt be basketball.

because all basketball players would die of the intense 1200V electric shock they would consistently be getting by connecting earth (by standing on it) with a point in2 meters height (their head).

John Eagle 6/17/2012 04:03:28 am

a

REPLY

John Eagle 6/17/2012 04:07:06 am

To "Carlos"...

I seldom listen to remarks by anyone that makes wild statements without validation, ... such as "You r so full of s??t" Carlos, people might like you and listen to you if you presented your "claims" in scientific and reality based formats. I understand, I once was like you. You can change. You'll be happier and more satisfied. Good Luck Carlos!

REPLY

Chuck 6/20/2012 03:42:38 am

AGREED,Stay away from laxitives and enimas

REPLY

Tony 3/16/2013 06:41:42 am

Tesla referred to all above unity devices as amplifiers. However, what Tesla meant by amplifier was that the increase in energy output did not come from the input. For example, a radio wave can be amplified by a vacuum tube circuit and the output radio wave has more power than the input radio wave - therefore it is above unity. Where did the power come from? The battery running the vacuum tube circuit.

The explanation in the article of how Tesla powered the car is complete and total nonsense written by someone with almost no understanding or knowledge of the topic. It does seem Tesla believed we are surrounded by energy in the aether that can be tapped the way wind, sun and rain can be tapped to provide power.

It was well understood back in the 1920's how you can pull power off of radio stations and electrical power lines without being physically connected to them and the methods are now illegal - yet they are the basis of the free energy devices that actually work on the websites I've seen that say "build this to prove it can be done and then send me hundreds of dollars for plans to some device that doesn't work and can't be built".

REPLY

thomas 7/8/2014 04:56:36 am

There is a report of a german engineer who claims he had taken a ride in the pierce arrow. According to this report tesla drove him to the niagara falls. So what? Niagara Falls is the location of the worlds first DC power plant. Guess what was right besides the road from new york to niagara falls. The power line from the plant to new york. So there You have your energy source. There are currently some projects in public transportation that use electric busses that are recharged by induction and that supplies 200kW of power. If tesla used the the powerline as an energy source for the car then the question is not "where's the energy from" but "how did he manage to extract that much energy from the field in a (compared to available induction devices) large distance"

REPLY

M. F. Elcher 6/16/2012 11:23:21 am

So this car ran at up to 90 mph for a week. What happened at the end of the week? Did it use up all the energy within the receive radius of the antenna? Break down? How much does an 80 hp AC electric motor weigh? I have an 11 hp 220V motor that drives a water pump. It is easier for two guys to lift a 90hp VW than it is for them to lift that 11hp motor.

REPLY

Eldon 6/21/2012 06:24:52 am

Actually, if you look up the story, I believe it goes that he was ridiculed as using some kind of black magic, and he was very bothered by this and dismantled the device, and refused to speak of it from then on.

REPLY

Dave 1/25/2016 10:46:10 pm

He was ... silenced

Phil 11/30/2012 10:11:26 am

1 gallon of gasoline = 6 pounds.
1 Suburban = 5000 pounds.

How can a 6 pound object inside a 5000 pound object move it?

"There is no energy in matter other than that RECIEVED from its environment." Dr. Nikola Tesla.

If gum cannot be created than gum doesn't exist. If gum cannot be destroyed than the flavor should never run out. Energy forces the car to the ground 100% effieciently with no fuel, no sound, no explosion, no battery, no generator, no friction, no resistance, no wires, no heat.

REPLY

Dipshot 5/30/2014 05:26:29 am

Now I am totally confused!

Captain Obvious 8/8/2014 01:32:22 pm

Never give a physics lecture when you are stoned.

M. F. Elcher 6/16/2012 12:18:58 pm

A motor/generator set is a useless waste of energy, even in your universe. Just take the power you were going to put into the motor and put it directly into whatever it is you wish to power, or store it in the new lightweight battery that you should invent, which alone will revolutionize the auto industry.

REPLY

oleg (http://teslabond.com) 8/7/2017 06:31:37 am

you prophet....

(/)

REPLY

Brad 6/16/2012 01:12:38 pm

An electronic amplifier using tubes or transistors will amplify small received signals and this signal can be amplified to be as powerful as possible but, no amplifier is 100% efficient. Whether one uses tubes or transistors makes no difference, you must provide a steady DC current and voltage to an amplifying circuit to provide output power. Since power is the product of voltage and current, in order to provide 80 Horsepower at the output of the amplifier, you must provide 59680 watts of power plus your losses in the amplifier. In other words if your amplifier is 33% efficient, you must provide another 120,000 watts of power to cover for the inefficiencies which are lost in heat. The total amount of power put into the circuit is 179,680 watts! This doesn't come out of the air! An amplifier simply makes a copy of a miniscule AC input current and increases it enormously by using the DC "working current" that is put into it. The "working current has to be provided by an outside source such as the power line or batteries. You can't get something for nothing. This is basic electrical theory and is learned in any first year electricity course. I am open minded about what Tesla did, but there is no way he did it with a conventional vacuum tube power amplifier!

REPLY

Jesse 6/8/2014 04:16:18 pm

I read somewhere that because the high voltage was high frequency , no heat was generated by the motor. I strongly feel Tesla was using frequency generators (or had some way of either indirectly/passively or having something like a FG making the volts a specific frequency) of some sort to make the voltage resonate at certain frequencies, but I don't know the mechanics of any of that stuff yet. Maybe sacred geometric shapes, crystals, all i know is that there is great power in doing this sort of thing.

REPLY

jim.vandamme 6/9/2014 12:26:26 am

I'm an electronics engineer with 46 years of experience in high power radar transmitters and high voltage.

Nothing of what you wrote makes any sense.

Sam 6/16/2012 01:43:37 pm

The author is an idiot. An electronic amplifier merely converts DC power into signal (AC) power. It cannot generate power by itself. Same applies to Darlington - which is just a configuration for high gain.
However, if Tesla could drive the car without plugging into a wall outlet - that is something worth looking into. A genius he was, probably he knew something unknown to present technology.

REPLY

Eldon 6/21/2012 06:33:11 am

Yeah, as I understand it, amplifying the signal, like a HV transformer, just amplifies one aspect at the expense of another- i.e. you can double the voltage, but the current has less wattage etc. So you aren't amplifying power, just modulating it.

This means that Tesla would have had to use his configuration to actually gain(receive) or generate a fairly large amount of electricity rather than just "amplifying" a signal.

So, while he might be able to amplify current from a 6v dc battery in the Arrow, to run the motor, it would drain quickly, and to recharge it he'd need some energy source or generation mechanism we don't know about.

I'm no expert though- that's just my understanding of it. It's a great story, and I commend the author on trying and encouraging the duplication of the achievement, but it's not that simple to do.

REPLY

Bob Loblaw 6/21/2012 06:34:22 am

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REPLY

martinp 5/5/2015 04:49:07 am

I agree, a commendable attempt but it still doesn't explain where the power is coming from. If the car was tuned into some powerful electromagnetic transmission of energy why would you need the parasitic load of an alternator??

Nate 3/10/2016 03:07:42 am

One of the wisest statements made on this page!

REPLY

PARIS 6/16/2012 02:53:26 pm

I think Nick would run his high voltage tower and use the air born energy from that to run the car.

REPLY

Cap'n Kirk 6/16/2012 05:21:39 pm

Of course Tesla was a genius...he was an ALIEN. (and they are some pretty smart cookies!). DUH!

REPLY

Vivek (http://aadivaahan.wordpress.com/2012/06/05/6666-beyond-carbon-beyond-time/) 6/16/2012 06:30:30 pm

For Immediate Release

13th June 2012

INDIAN INNOVATOR HAS SOLUTION TO END THE AGE OF OiL : PUTS OUT CHALLENGE TO THE WORLD :

Bangalore based visionary, Polymath and long-time blogger Vivek Chaturvedi today put out a challenge to a world begging for a solution to the Age of OiL.

Writing from his bloffice in Bangalore, Vivek stated in his latest post on June 6th (6666, a date he says was especially powerful, a trigger missed by the world at large) that he has the Definitive Engineering Solution to gracefully end the age of OiL.

In a desire to make the solution open to the public at large, Vivek has asked 3,000 brave folk to come forward, purchase his Book/DVD/CD and the unique Certificate of Sharing.

With-in 90 days of the 3,000th purchase, he says he will release a fully working model to the world. Here is what he says he will show:

An Electric Car that costs 50% less than existing models, will travel with a range extended by up-to or exceeding 200% of the current state-of-the-art, will need no subsidy, will allow for "backyard" conversions of existing vehicles in a safe manner, will allow for the blossoming of a Electric Vehicle Cottage Industry and most importantly, will exceed all the safety standards of current vehicles.

His work, he said, will reduce global oil consumption by up-to 40% with-in 2-3 years (depending on the pace of adoption, far exceeding any mandated lowering of such consumption. The impact on the world is expected to be tectonic.

The core concept is un-deniable, a fact Vivek says he is willing to prove to any serious, large investor.

Referring, only half-jokingly he insists, to this as the ultimate pre-IPO opportunity for the public on a set of technologies that will transform our world, Vivek is open to approach by honest media for interviews.

Please visit:

http://aadivaahan.wordpress.com/2012/06/05/6666-beyond-carbon-beyond-time/

He urges you to go to the comment section, and read what people have to say.

This IS the time, Vivek insists, to launch the first truly Aquarian Project, and is looking forward to cohorts who will come to the table and participate.

Vivek's Product concepts and designs, his art and his music have been variously described as jaw-dropping, graceful, piercing, brilliant, innovative, disturbing and something, as one lady insisted, she was glad she had lived long enough to see.

Contact:

Vivek Chaturvedi
Bangalore, India

vivekanand@squareandc.net

Skype: vivekglobal (please state your interest and purpose in the contact request, much appreciated)

REPLY

captain_obvious 6/9/2014 01:51:32 am

Guess Viviek died of an overdose of whatever he was smoking, because there haven't been any updates.

REPLY

thomas 7/8/2014 07:27:48 am

No. He's on a test-drive. Fact You didnt hear from him for 2 years only proves how long you can ride his car without interuption....

Or maybe he will only release his invention when he has spend the 350.000 dollar he wanted people to pay for his DVDs....

Captain Obvious 8/8/2014 02:29:00 pm

Perpetual motion: the endless supply of suckers to support the non-stop appearance of scammers.

masthead 6/16/2012 07:04:46 pm

Tesla use a consumable battery that had to be constantly fed with sacrificial metals because he had no generator hooked up to that Pace Arrow....moving on....he did not have a receiver on board....his device was a radio transmitter attached to two attached resonate cavities [12"x12"x6"] that were tuned with a 3" x 1/4" metal rods [one per cavity] which would produce between 50-100hz. One of these cavities would control the speed of the motor by varying the resistance to the tuned circuit of the two banks of vacuum tubes that were matched to the other cavity. Speed on the motor was achieved by varying the tuning of matching reactive cavities [which could be duplicated by twin frequency generators firing 180 degrees out of sinc]....the antenna would be wrapped with a coil that was fed back to the transmitter and the thigh antenna & attaching cable was the current path back to the motor...a sudden brief burst into the atmosphere would supply a momentary potential difference that could be harnessed by the motor.
the transmitter was able to create atmospheric/aetherical potential difference that could be wicked, via the thick antenna, into the motor which was reference of the other transmitter's out of sinc signal back at the frame and into the other motor's tap. This other reference would be 180 degrees out of the 1st signal at the antenna.
masthead

REPLY

donald argall 11/22/2013 02:28:55 pm

my grand father and tesla worked together in colorado sp try using some radio active wire. look in 310/3. that should help cler up some problems

REPLY

Bob 8/8/2014 12:55:58 pm

What size resistors did he use in wiring the vacuum tubes ?
Is there a wiring diagram that shows which pins of the 8 are to be wired ?
Bob

REPLY

Captain Obvious 8/9/2014 02:59:35 am

Bob, let me explain.

The legend says that Tesla got his tubes from a radio store. With the technology available at the time, there is no way he could have rectified this mystery wave and controlled an 80 HP electric motor with eight radio tubes in his glove box. There wasn't that much energy that he could pick up on his antenna (cut for about 200 MHz). Existing radio tubes couldn't work at that frequency.

The hoax needs embellishment before it is believable. Like, the name of the guy telling the story needs to be a real guy, not a fictitious nephew. Also, the boat company he was supposedly negotiating with needs to be named, so records can be checked and stories corroborated (or not). And all the people who worked on the car...not a peep out of them?

And nobody else, from the dawn of history, has ever identified this mystery energy, even though it would mean an instant Nobel Prize and accolades far surpassing Newton, DaVinci, Einstein? All the smart people know it's bullshit, but the backyard tinkerers and hucksters press on, selling their snake oil.

Bob, there are better things to do with your time and money. God will send you most of the energy you need today from His fusion reactor 93 million miles away. Heat your water, charge your batteries.

Mike S 6/16/2012 09:33:09 pm

I was an electronics tech for 19 yrs, I see a lot of general discussion but no clear explanation of where the energy came from. If it's as simple as throwing up an antenna then why don't you have a youtube video of you driving a car or golf cart around using the same approach? Something is missing from this picture. We do not know what the energy source was for the car incident, if it really happened.

REPLY

masthead 6/16/2012 10:18:06 pm

the problem about all this energy that's everywhere is there is no potential difference we can grab hold of to harness any on it. we have only one side of it! it's like birds sitting on a high voltage transmission wire...if the bird had legs that would allow one foot to stand 500 ft away from the other foot, the bird would be electrocuted because it would then have potential difference. transmitting a LOCAL electronic burst transmission is that would create that potential difference that could be induced to enter into a device [like a referenced motor] and that seems what Tesla was doing.
When I was 1st writing about this I got a stroke and awoke on the floor a day later with a phone thrown next to me. When I wrote about this after I recovered I got another stroke! Someone mysteriously paid off my $50k hospital bill immediately and my life has been very strange ever since; but, several alphabet agencies know exactly where I live even though I have takes steps to avoid that! [they have made it a point to let me know]

REPLY

masthead 6/16/2012 10:21:57 pm

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REPLY

(/)

masthead 6/16/2012 10:32:41 pm

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REPLY

guest 6/17/2012 01:11:52 am

My comment is minor, but in your article, don't you mean CO (carbon-monoxide) instead of CO_2 (carbon dioxide)? It is CO that is the most dangerous element in car exhaust...

REPLY

Need to know 6/17/2012 02:29:31 am

So, maybe I'm not getting it. Is the schematic above what you need to follow how to covert your car to run on free(?) electricity?

and has Zach actually built it and runs his car this way???????

REPLY

[Rick Potvin (http://www.network54.com/Forum/737482/)](http://www.network54.com/Forum/737482/) 6/17/2012 03:30:00 am

I specialize in moderating threaded discussion forums. Maybe we can have a better conversation using the format I've created to continue this discussion here...
http://www.network54.com/Forum/737482/

REPLY

Patrick Sullivan 6/17/2012 04:28:04 am

Tesla was asked: "Where is the energy coming from that powers your machines?" To which he responded: "I don't know, but I'm glad its there."

Dr. Henry Moray was asked the same question and responded: "I don't know, but I think it has to do with particle size."

Is it a curiosity that both men produced high levels of free energy from the surrounding space, yet were unsure of where it was coming from?

We learn to think of electricity as water to help give us a clue as to how it flows.

How about we think of water that is at the temperature that makes part of it into steam?

The steamy side is our volts, intensity we can claim it.

The heated water is our amperage, that's the planets magnetic side we can claim as density.

Think of the steam side now as half spin particles; electrons we call them. Volts is how we measure them.

Think of the water side as full spin; magnetic. Amps is how we measure them.

The electron is 1 mass unit; 1 emu.

The magnetic can be reflected as 3600 emu.

All mass is electric in nature.

Mass is comprised of both sides of the thing we call electricity; amps and volts.

Magnetic and electrical components comprise electricity

When the 1 emu electron is displaced from its original orbital position, the 3600 emu's of the full spin magnetic side are released and begin to act in a rotatory motion.

A relativistic time shift in the steam side (half spin , electron measured as volts) of our combined electro- magnetic spectrum, (the thing we call electricity) makes the 1 emu cause 3600 emu to cause a static field reaction.

The magnetic full spin measured as amps, remains duty bound to attaching the coil to the static field that it was first inserted into.

The 1emu electron removal (relativistic time displacement will do the trick), allows the 3600 emu of the full spin magnetic side to begin rotatory motion; this will produce an interaction with the power of the Cosmos pouring energy in to maintain the original position; the 4th dimension of our heater coil and full spin 3600 emu particle.

Could we say that Dr. Moray guessed exactly right? Looks like it doesn't it?

The full spin particle engages the coil of our heater or motor, and firmly attaches coil to the static; zero point field(s) of our planet.

That's it.

Classical engineering does not accept that a static field can be harnessed for the extraction of energy.

Yet, the static fields possess the greatest amount of energy available to us.

A vacuum tube produces a separation between the half and full spin sides of electricity, analogous to a semiconductor device.

Tesla powered his electric car with vacuum tubes. Dr. Moray used solid-state components. It appears that he may have invented a transistor, possibly a triac, before we had any idea of what he had invented.

These over unity free energy devices are inertial field generators.

Velocity power sources is a correct name for them. Our 600 mile per second flight through the Cosmos generates an opportunity to tap into the power of the Cosmos.

All free, all clean unlimited heat and electrical energy 24/7 from now until eternity.

For a details of inertial field generators, you can read the e book:

"Free energy here and now and then: Velocity power sources."

Provided within is a more complete technical explanation of how they operate. The hope is you may be inspired to start building them.

It's available at LULU to download for $2.99

http://www.lulu.com/shop/search.ep?keyWords=free+energy+here+and+now+and+then&categoryId=100501

REPLY

> **Captain Obvious** 7/8/2014 12:41:28 pm
>
> Instead of selling your books for $2.99, just demonstrate that your alternate physics is based on fact and your Nobel Prize and billions in royalties are waiting.
>
> REPLY

LOLWUT 6/18/2012 03:02:10 am

Listen, missy - in our house we obey the laws of thermodynamics!

REPLY

(/)

Thermodynamics 6/21/2012 02:22:40 am

None of the laws are broken, they are very much correct. However "closed system" is a word play to fool the lesser minds.

REPLY

The Expert 4/20/2014 11:26:40 pm

There is only one truly closed system when it comes to thermo dynamics and that is the Universe it'self .

jpdoorguy 7/5/2012 06:56:40 pm

Nice!!!

REPLY

Bojangles (http://ultralight america) 6/18/2012 05:55:59 am

It really comes down to the question "What happened to the Pierce Arrow vehicle? What happened to the Lee Rogers Buick station wagon that drove on a compressed air supplied V8 engine? What happen to the Clem vehicle who's engine ran on vegitable oil? Spend your time to find the original Tesla Pierce Arrow vehicle and prove it really existed then I will believe your story.

REPLY

chris 6/18/2012 06:08:54 am

An alternator can only provide power if it is being fed by a motor, (usually the engine connected via a link). So how did Tesla get the alternator power? Free energy?

REPLY

The Expert 4/20/2014 11:35:42 pm

The energy required to tap into the aether as Tesla called t came from the battery and the alternater merely kept the battery power levels topped up as in a modern petroleum driven car today .. The main energy source as claimed by Tesla was the aether which is all around us just as air is . The only mystery remainng is how did Tesla manage to tap into the energy provided by the aether . It's hardly surprising that he was very cryptc and secretive about this line of his work considering how his enemies would stop at nothng to destroy anything he unveiled that was a threat to their vested interests

REPLY

emotor (http://www.neotreksoftware.com) 6/20/2012 12:11:11 am

Not my area of expertise but we do know the sound amplifier
example requires external power.

I can say however that of the thousands of carcinogens that are exaust from fossil fuels CO2 is not so but it is a contributor to global warming.

Does anyone know how the transisters amplify the smaller current
from the antenna? Do they some how draw in or concentrate or
attract more atmospheric electrons or EMF wave frequency?

REPLY

Andrew 6/20/2012 02:53:52 am

Sorry, poorly thought out article. I am a FE buff and big fan of Tesla but this article does not describe the operation of electronics properly at all. That plus the interchangability of volts and current with regards to useable power is also not correct.

I will not go into details because its not worth arguing in this format, but if you rty to build a circuit based on this you will find out for yourself.

REPLY

Torbjorn 6/20/2012 04:11:42 am

Hi you all,
The schematic presented with a 555 timer circuit, a 7805 voltage stabilizer and three power transistors in parallel to feed an internal combustion engine ignition system is not relevant or interesting as I see it.
The interesting part in this is setup is the possibility of varying the the frequency of the primary input of the ignition coil.
Any way it´s a very poor electrical/electronics schematic and I would very much like to know how this fits in to the subject at hand.

Anyway I, can personally, after experience, say that there often is, a great potential difference between the ground (or earth) of an antennas ground and the ground of the grid (which most of all electrical devices are connected to).

The issue of sufficiently "grounding" electrical installations comes to a "common ground" for all installed electrical equipment and also to mitigate electrical storms and there destructive force on electronics.

Normally the issue of connecting all installed equipment that consume electrical power and make them have a "common ground" is very much linked to the equipment's power consumption, i. e. the current they consume.
This is because of potential (voltage) losses in the cables that supply the equipment. So the return to ground is not at zero.
It has also to do with the "power factor" that is present in all equipment that is not purely resestive. I.E. inductive or capacative
in nature.
Any way, for a spark to make a jump in air of one mm it has to have a potential of at least a couple of kV.
What is it then that "sparks" when one attaches a receiver to the antenna? Why do one sometimes get "electrocuted" when connecting antenna cables?

As I see it there is no way of explaining this from a "common ground perspective" as I have learned in school.

There just have to be a electrical potential between the antenna and earth (ground).

Thank you all!

REPLY

Alex 6/20/2012 07:44:34 am

Nikola Tesla's Wireless electricity idea is pretty cool! No combustion engine and no pollution. I hope soon we will have clean and safe fusion reactors sending wireless electricity through the air to power our cars. http://www.youtube.com/watch?v=ro5-QYqqxzM

REPLY

Ash 6/20/2012 06:06:51 pm

Tesla's Pierce Arrow story is an old Internet hoax. Google Tesla Pierce Arrow and you'll see plenty of people have fallen for it and then researched it to find it never existed. You sure fell for it!

REPLY

> Rick (http://www.network54.com/Forum/737482/) 6/24/2012 07:41:35 am
>
> And if that's your position, then how far does the hoax go, do you think? Was Wardenclyffe a hoax? How about the light bulbs simply plugged into the ground at Buffalo? If you're going to call the car a hoax, then tell us how far the hoax goes... or does it stop at the car?
>
> http://www.network54.com/Forum/737482/message/1340563271/HOAX
>
> REPLY

(/)

Dave 7/22/2012 03:09:29 am

well said rick, why do people Just have to put their negative crap. there is a few constructive questions on here. why can't we work together instead of against each other

EMILIA 6/21/2012 12:59:32 am

i am not understand this " How was he able to drive for hours, at speeds as high as 90 mph without stopping to recharge? "
And after that , what happening ? How you can continue the way ?

REPLY

Administrator (http://admin@apparentlyapparel.com) 6/21/2012 01:19:16 am

We believe he simply pulled over and rested if the car stopped running, It would take up to five hours to recharge the battery. Imagine a car that has antenna that converts static electricity into a useable form of energy. That is what Tesla did. You just would need to pull over and let the car charge before again having enough charge to continue. Hope that explains things a bit. Not saying it happened, just saying that is what we have heard.

REPLY

Emilia 6/21/2012 07:01:52 pm

THANK YOU . I am glad to read this article . It is a good explanations for an amateur like me , especially what is a transistor , what is semiconductor , what is Darlington transistor ". the explanation it was very clear , especially for a woman , like me .
Thank you . Emilia

Wire Binding Machines (http://www.gbsupplies.com.au/machines-equipment/binding-machines/wire-binding-machines.html) 7/30/2012 02:55:13 am

Really appreciate this post. It's hard to sort the good from the bad sometimes, but I think you've nailed it!

REPLY

Electric Gates (http://www.electricgates-uk.co.uk/) 8/21/2012 11:48:17 pm

Really I am impressed from this blog post about Wireless Electric Automobile....the person who created this post is a genius and knows how to keep the readers connected...Thanks for sharing this with us. I found it informative and interesting. Looking forward for more updates…

REPLY

Bubi Goevy 8/28/2012 08:10:30 am

If this works, you will make much, much, much money with it. Everyone waits for a car like this. Why did noone start making money with this idea? I know many people who will buy such a car immediately without looking for the price! So don't discuss - start making money!

REPLY

gaftech 9/21/2012 01:23:12 am

wooooooooooow. their re many ways to get free energy/electricity. i av tried manyways of producn free energy/electricity, d result i got made me to believ dt its possible. any 1 who loves to try somtin new will believ dt their's nothin impossible. i ve invested alot b4 i got to believ it, even if wht i was very small at least i got 160watts which power view things...very soon every 1 will see d standard 1.......TRY YOUR BEST,U LL DISCOVR SOMTIN NEW.........

REPLY

Gaftech 9/22/2012 07:11:39 pm

Their re manyway to get free energy/electricity.. I ve invested alot b4 i got to discovered it even if what i built was very low 150watts, it powered just view things at home at least i still believe its real...
Em d type who love to try things,doin many xperiments and I listen to argument but never say a single word.VERY SOON every 1 will see my work cos em workn on d standard to present to pple.....

REPLY

Jesse 6/8/2014 04:30:33 pm

so, what ever happened to this 150 watt design you talked about a couple years ago?

REPLY

Captain Obvious 6/9/2014 12:17:26 am

Pick the most plausible:

Aliens came and took it back.

Men in Black/oil companies came by and he vanished.

He sold shares, absconded with the money, and is now living somewhere in the south Pacific.

He's still selling books about it, but never got it "refined" to where it actually works.

He studied electronics and physics, and finally realized that it was impossible.

Captain Obvious 6/9/2014 12:18:13 am

Pick the most plausible:
- Aliens came and took it back.
- Men in Black/oil companies came by and he vanished.
- He sold shares, absconded with the money, and is now living somewhere in the south Pacific.
- He's still selling books about it, but never got it "refined" to where it actually works.
- He studied electronics and physics, and finally realized that it was impossible.

Nick 10/23/2012 08:07:11 pm

Amplifiers do not creat power. They modulate power in response to a signal. Same for a Darlington pair. An alternator in car needs external power/energy to drive it to make electricity. That power has to come from the motor. But the motor and alternator cannot keep driving each other: they will stop very fast. A car alternator cannot go NEAR to powering an 11KW motor. At most you might 0.5 - 1.5 KW. The car's coil can take a low voltage and make it a high voltage...but there is a MASSIVE loss of current. Again, there is NO input of power. None of the above explanations make sense, whether Tesla did what is claimed or not.

REPLY

ZAG 12/4/2012 06:33:22 pm

Nothing is impossible

REPLY

Ivan 1/13/2014 09:08:48 am

Absolutes are imposible. There is allways something bigger, better, smaller, stronger, weaker, faster, slower.........

REPLY

Andreas 1/2/2013 07:34:51 pm

Has anyone built this cirquit for testing ?

(/)

REPLY

jason 1/22/2013 07:13:06 pm

this story is interesting but missing one key point....ok there may be radiowaves that can be harnessed...free radio waves ...there are all kind of free waves out there covering the whole frequency spectrum...the problem is...these waves need AMPLIFICATION.....and yes...amplification can be done using transistors or valves......but the problem with this story is you can amplify any signal.....but the amplification process is what takes power.....this story does not touch on where the source power for the amplification of the signal came from...so i suggest if tesla really did build this car that ran off waves of some sort......its not really signal amplification that is the genius of his device..simple transistors and valves achieve just that..the genius is what gave him the power to amplify the signal...ie change it to something powerful enough to turn the motor.....as the amplification process requires power....

REPLY

Rino 1/28/2013 06:59:06 am

If the valves were effectively diodes they would just rectify the 'noisy' signals coming in.
Therefore the need for the power supply current would be eliminated as the aerials are supplying it.
I'm just a tinkerer but surely there must be someone out there to put this together. It's up for grabs!
Anyone working on this, don't give up but keep your head down for the men in black. Too many promising inventors have just disappeared..

REPLY

blublood 2/3/2013 09:41:38 am

Writings on Tesla's electric car state he utilized energy derived from his 'Tesla coil'. His goal was to mount giant Tesla coils on top of towers at multiple locations around the US/World (like a top of Niagara Falls) to power his devices from the aether.

REPLY

Gary Parsons (http://n/a) 2/11/2013 06:35:22 am

Great explanation. Now,if electricians can do this, why haven't they??

REPLY

> **rick** 3/21/2015 08:02:03 pm
>
> Because electricians are trained in practical ways which do not disrupt the profits of the powerful. We continuously are discovering things throughout time which provide additional information which disprove what the "experts" thought to be case (the world is flat, you will sail off the edge, etc, etc.). At some point the error of a closed loop system which current day "experts" claim to be absolute will be as silly as actually sailing off the edge of the Earth.
>
> REPLY
>
> > **Matt** 4/15/2016 12:17:08 pm
> >
> > Careful the Flat earthers will attack.

clarity way (http://www.clarityway.com/) 2/19/2013 05:22:38 pm

Modern Valve Amplifier is great. The most remarkable features of these transformers are their extremely wide frequency ranges

REPLY

Free Rider (http://scutere-electrice.webs.com/dincolodeaparente.htm) (/) 2/26/2013 06:08:44 pm

Eu cred ca va scapa un lucru foarte important.Tesla putea sa trimita curentul wireless iar dispozitivul pe care la creeat capta acest curent pe care el il trimitea in eter.De aceea nu avea nevoie de baterie .Daca aveti acasa un glob cu plasma puteti incerca sa aprindeti un neon fara fir .Acesta emite energie iar neonul o capteaza din aer si se aprinde.Tesla nu era sarlatan ci oamenii erau inculti si ignoranti.Toti o dau ca nu exista energie gratuita ca nu scoti mai mult decit bagi .Problema este ca scoala are grija sa iesim idioti si sa nu mai putem gindii lucid.Cum sa nu existe energie gratuita cind tot ce ne inconjoara este energie si este gratuita.Pina la o absolut adica -274 grade C si vid restul este energie.Energia circula de la pozitiv la negativ cum bateria se descarca de la 12v la 0 pina ajunge la 0 avem energie.Deci de la 35 grade C pina la -274 grade C avem energie de consumat..Un exemplu simplu de a scoate mai mult decit bagi este lupa.Intr-o parte ai 35 gr C si in partea cealalta peste 100 gr C Daca temperatura pe Tera era de 90 gr C mergeam cu apa folosind aburul.Este clar ca aceste energii ne sunt furnizate de soare sau de gravitatie sau din alte surse deci nu sunt gratis ,adica cineva le produce, dar sunt gratis pentru noi le primim gratuit.Deci pentru toti idiotii care spun ca nu ai cum sa scoti ceva din nimic este adevarat numai daca acel nimic este -274 gr C in rest ,tot ce depaseste pozitiv aceasta temperatura inseamna sursa de energie..Prin racirea temperaturii existente putem extrage lucru mecanic cum spunea Schauberger.Natura face asta frecvent numai ca noi suntem prea ocupati cu legile invatate la scoala unde se spune ca nu poti sa produci energie decit din benzina sau mai stiu eu ce surse pe care trebuie sa le platesti baietilor destepti care au grija sa ne invete ca numai sursele lor sunt eficiente.Un test simplu este sa bagi in congelator o sticla cu apa calda si o sa vezi ce face vacumul creeat prin racirea sticlei.Vortexurile creeaza un astfel de efect si prin racire se creeaza vacum deci lucru mecanic.http://lefo.wikispaces.com/Tubul+Vortex Numai bafta si reflectati la cele spuse .http://ltnbenergie.webgarden.ro/menu/tipuri-de-energie/6-energia-gravitationala

REPLY

Wolfram Barren 3/6/2013 02:05:03 am

You guys are real funny! We work with free energy (e.g. water) and there are so many people having published and presented their vehicules and engines to the press and the public, but how strange and mysterious, all these guys died or have been killed. You can not be serious, definitely not! And why yre you guys not doing the first step? Affraid of BP or Shell? Like BMW in the 80's while working on an HHO car?

REPLY

vinod kumarsaini 4/17/2013 07:31:12 am

kay tum mary projakt ko lay saktay ho may car ko bena endan ka Dodasakta hu

REPLY

Bruce McBurney (http://www.himacresearch.com) 7/6/2013 04:21:05 pm

After years of researching 100 MPG systems suppressed by the oil companies and building one to get 70 MPG in a Dodge 360 CI maxi-van, putting out a book that explains it money back if not convinced and selling over 2500 with only 2 refunds putting 90 % of it free on web site www.himacresarch.com because i wiould like a planet left for our children. I was told that they offered Tesla 150 million for the technology in front of liars (Lawyers) and shrinks (psychiatrists) that declared anyone that could turn down 150 mill for an idea must be crazy so the locked him up for the weekend and fried his brain, on Monday his lawyers got him released and he then went to live with the pigeons, the car disappeared, he never filed another patent. This extraordinary man became a vegetable, if you do not believe they could do this, Google Titanic and Olympic switch, where they sunk that ship on purpose they killed John J Astor the richest man then, a friend and would be backer of Tesla. All people that opposed bankers got free tickets to Titanic, one year later the fed reserve, banks of Canada and England were taken over and we live in debt based economy

REPLY

JacobChiong 11/12/2013 04:33:48 pm

This article is wrong on many fronts. The energy received by the antenna is very, very small. You talk about amplifying that signal using power from the battery. Then using the amplified power to drive the motor? If antenna signal is 0.00001W, and you amplify it to provide, say, 300W, you are possibly draining the battery at 500W, where 200W is expended as heat and return paths in the amplification system. So you are draining the battery at 500W and utilizing only 300W for the motor. We won't even now worry about the antenna's 0.00001W. The battery will in no time run flat. Using the battery to drive the motor thence the alternator,etc, is nonsense. You don't just cobble together different information from different context and then hope to have a coherent whole. I think Tesla got it working but definitely not in the nonsensical way you wrote. I belief he figured out a way to harness the thermal energy of the air/water molecules by some sort of resonant circuits and thereby forced or persuaded a rapid drop in the thermal energy of the molecules surrounding the antenna and achieved the same phenomenon of lightning where charges are released and collected by the same antenna. As radio waves get attenuated at certain frequencies that are resonant frequencies of air

and water vapour, and thus energy is transferred to the molecules, Tesla may have worked out the frequency to use to force the reverse - force the molecules to give out electrical energy and a corresponding drop in temperature. The lightning effect may then be also called into play. In this way, the charges so collected may far exceed the power needed to supply the 'persuading' resonant frequency. Just guessing, as Tesla is the genius that we are still guessing about a century later.

REPLY

sean 11/30/2013 01:46:04 am

I don't know if Patrick is exactly right. But he is closer. His book is a free download from lulu now. (I haven't read it.)

Tesla thought diodes were unnecessary and a waste. So eliminate those from your design. Also he had pretty much abandon AC by the 30's so eliminate that from your equation.

REPLY

Captain Obvious 11/30/2013 04:51:03 am

Sean, do you have a link to Patrick's book, or title? Why would Tesla say diodes were a waste if he abandoned AC? They have losses, but sometimes you need DC (like, powering electronics).

REPLY

Doug 12/24/2013 03:25:09 pm

most do not seem to get it.... I can run a copper wire 100 feet up put in a ground rod and run a motor. in the way you would wire a transistor and diode setup you would simply split the input source or add more antennas to get said amplification to achieve the power gains. I would suggest you look up electrostatic motors and www.laserhacker.com (we have all been lied to for so long it is sad)

REPLY

Captain Obvious 12/25/2013 12:18:57 am

Yes, Doug, energy is free. Now, if you can harvest 1/100 watt continuously from your motor, and your power company charges you 16 cents per kilowatt hour (greedy bastards!!!!) you will avoid paying them 1.6 microdollars per hour. And if you put up 71 million identical generators, you will make a million dollars worth of electricity in one year. So, get going. First, you need to measure how much power you are collecting.

REPLY

Peter 4/4/2014 02:23:47 pm

You do not understand how amplifiers work, and because of this the logic of your post does not make sense.

You need to understand that amplifiers are just modulated power supplies. The real energy comes from the power supply, not the signal.

The modulated power supply (which is a DC power source) is simply a larger facsimile of the input signal. It is not amplifying the input in energy terms.

I understand how you have made this error in your understanding of how amplifiers work. This is quite the norm.

Please note that so far, no 'free energy' product, or theory, breaks the law of conservation of energy , but they do 'break' the so called 'Second Theory of Thermodynamics'; this theory is incorrect and always has been, and has been debunked for many years by any physicist worth listening to.

Although the main thrust of your explanation is founded on an incorrect understanding of amplifiers, I do not disagree with some points on this post. For example, I do myself believe that Tesla's car energy system was essentially a transmitter first, and then a receiver second. I am happy to expand on that later if you are interested.

I fully understand and appreciate the amount of effort it has taken you, and your colleagues, to stick a stake in the ground for this mystery, and hopefully act as a seed to grow and develop.

kind regards
Peter

(/)

REPLY

Captain Obvious 6/23/2014 12:16:40 pm

"For example, I do myself believe that Tesla's car energy system was essentially a transmitter first, and then a receiver second. I am happy to expand on that later if you are interested."

I may regret this, but please do go on.

REPLY

Peter 4/4/2014 02:27:34 pm

P.S.

My apologies, clearly my thoughts support what commenter 'Brad' wrote.

REPLY

Robert Keller 6/23/2014 08:58:24 am

"the free electrical energy that surrounds us – 100 volts/meter of free energy."

The joule is the unit of energy, not the volt.

Take a copper rod and pound it into the earth. Hold up your antennae above the earth. Attach a resistive load to the two and put an ammeter in series.

Your available power is I^2 x R which is the available energy per second.

REPLY

thomas 7/8/2014 04:55:12 am

There is a report of a german engineer who claims he had taken a ride in the pierce arrow. According to this report tesla drove him to the niagara falls. So what? Niagara Falls is the location of the worlds first DC power plant. Guess what was right besides the road from new york to niagara falls. The power line from the plant to new york. So there You have your energy source. There are currently some projects in public transportation that use electric busses that are recharged by induction and that supplies 200kW of power. If tesla used the the powerline as an energy source for the car then the question is not "where's the energy from" but "how did he manage to extract that much energy from the field in a (compared to available induction devices) large distance"

You must be aware that tesla was already sick and tired of other people stealing his ideas at that time. So he started to obfuscate was he was doing and therfor didnt reveal the real energy source. You see how successful he was. People chasing all kinds of miracle "free energies" instead of thinking about efficient ways of wireless enrgy transmission. Unfortunately this also means that the tesla car would not solve any environmental problem as long as we do not have 100% renewable and clean energy sources.

REPLY

Captain Obvious 7/8/2014 01:00:22 pm

The radiant energy from a DC potential is normally almost nil and would certainly not power a car from an overhead DC power line. Even 60 Hz lines would not radiate appreciable power. Induction is done at high kilohertz frequencies using multiple turns of current carrying wire; a single straight conductor would radiate very little until it was an appreciable portion of a wavelength long. But the return current in the opposite wire would tend to cancel the field, and the wires were close together on a pole and the field would almost cancel near the ground.

REPLY

K A CHEAH (http://-) 11/12/2014 10:45:47 pm

CAN ELECTRICAL POWER BE TRANSMITTED AND RECEIVED WIRELESSLY LIKE WHAT MR. NIKOLA TESLA HAD DONE ? IF THIS POSSIBLE THERE SHOULD NO PROBLEMS FOR HIM TO HARNESS ELECTRICAL ENERGY FROM THE ATMOSPHERE AND THEN AMPLIFY THE ELECTRICAL POWER TO RUN HIS PIERCE ARROW AC MOTOR CAN SOMEBODY MAKE A REPLICA TESLA BLACK BOX TO RECEIVE AND AMPLIFY TO RUN AN ELECTRIC CAR SAY A MODERN ONE LIKE A NISSAN LEAF BY RE-CHARGING ITS BATTERY ON THE GO WITHOUT THE NEED TO PLUGIN INTO WALL SOCKET BUT FROM A TESLA BLACK BOX WITH AMPLIFYING VACUUM TUBES INSTEAD AND ANTENNA OK? THANKS

REPLY

Captain Obvious 11/14/2014 02:21:42 pm

To your first question, yes, that is magnetic induction, and it is well understood. Your second statement is a non sequitur. There is not enough energy in the atmosphere that you can capture with such a small antenna. You cannot amplify energy, you can only amplify signals, using your internal power supply, at less than 100% efficiency. You lack basic understanding of physics and electronics. And, the use of the caps lock key.

REPLY

K A CHEAH (http://-) 5/22/2015 04:35:49 pm

CAN THE AUTHOR OF THIS ARTICLE GET AN ELECTRICAL ENGINEER TO MAKE A TEST PROTOTYPE OF THE TESLA BLACK BOX WITH ANTENNA TO RECEIVE AND AMPLIFY ELECTRICAL ENERGY TO RUN THE EQUIVALENT SIZE MOTOR AS PER THE NIKOLA TESLA'S ELECTRIC CAR SIMILARLY AS PER DESCRIBED ABOVE AS THE SAID THEORY NEEDED TO BE REPEATED AND PROVEN TO ACHIEVE WIDE ACCEPTANCE AS CAPTAIN OBVIOUS DOUBTED WHAT NIKOLA TESLA DID ABOUT 100 YEARS AGO OK???

Captain_Obvious 10/28/2015 07:20:38 am

OK, K.A., I'm an electrical engineer and now retired after 46 years of research at the Air Force Research Lab in high power RF radiation (mostly radar). I've got the time and the experience.

Tell me where the power is coming from and I'll build a gadget to receive, transform and use it.

Show me a schematic and I'll build a modern equivalent, using the latest solid state devices and magnetic materials.

Don't ask me to do your job. I've looked, and there is no ether power, no free energy, no Pierce Arrow, and no schematic. None of the rumors about Tesla's car make any sense.

MQ 11/17/2015 06:47:40 am

Tesla electric car that had nothing to fuel it but an antenna picking ambient (the sun is the main source of this) electrical radiation energy leaking through the earth's magnetic shield through a process called magnetic re-connection observed frequently by a European space probe and considered to be a permanent and significant phenomena by the scientists using it!

Hans 11/26/2014 02:35:01 am

I really think this is interesting, but referring to an ordinary antenna on the roof and that this is tapping into 200V of current is crazy. How to stop the any radio amateur antenne to fry every possible radio connected to it?
I also read about the vacuum tubes that supposedly was used. They came to the marked in 1937 - a little late to be plugged into the Tesla magic cube.

REPLY

ed 3/20/2015 03:43:32 pm

I'd say that an 80 hp electric motor with the class A insulation that was used at the time might not fit under the hood of that Pierce Arrow...

REPLY

K A CHEAH (http://-) 5/22/2015 03:52:28 pm

CAN THE AUTHOR OF THIS ARTICLE GET AN ELECTRICAL ENGINEER TO MAKE A TEST PROTOTYPE OF THE TESLA BLACK BOX TO RECEIVE ELECTRICAL ENERGY AND AMPLIFY IT TO RUN THE EQUIVALENT SIZE MOTOR AS THE NIKOLA TESLA'S ELECTRIC CAR SIMILARLY AS PER DESCRIBED ABOVE AS THE SAID THEORY NEEDED TO BE REPEATED AND PROVEN TO ACHIVE WIDE ACCEPTANCE OK???

REPLY

Captain obvious 5/23/2015 03:19:53 pm

I am an electronics engineer who has done high power RF R&D since 1968 for the Air Force Research Laboratory. I've designed and built radar transmitters, and antennas at various frequencies.

If you come up with a theory of where this 50 horsepower to power Tesla's Pierce Arrow came from, I will build and operate a test device to demonstrate it.

It can easily be demonstrated that there is not enough static or RF field within a reasonable sized aperture volume to develop this amount of power. There is more energy radiated by the sun, which can be converted to electricity; but not enough to power a car continuously with a collector the size of said car.

So, work on your knowledge of physics and electronics. And, try to find the caps lock key.

REPLY

Captain Obvious 7/4/2015 09:16:55 am

Still waiting. I guess "math is hard". Physics is even harder.

Ming Tea (http://Mingtea.com) 7/4/2015 08:32:15 am

U bee Crazy by ignoring all the laws of physics. You can not get somthing fer nuttin

REPLY

Clay king 7/10/2015 09:53:48 am

Are sail boats free energy? Do theybreakYOUR laws?

REPLY

captain Obvious 7/14/2015 12:25:24 am

You get air and sunlight for free.

Sunlight makes wind and rain, which you get for free. With those you can build windmills and dams and get lots of free energy . You can build PV farms that run your A/Cs and factories by day.

So, plenty of free energy to be used. This rumored Tesla free electricity car is a myth, however. There is not enough static electrical energy in the air for you to collect an appreciable amount and run a car off it.

And yes, I read read read. I also have a masters' degree in electrical engineering and worked in several R&D labs which would be glad to have such a source of "free energy". But guess what: it doesn't exist.

REPLY

MQ 11/17/2015 06:59:46 am

It's not the electrostatic charge of the atmosphere! This is not how Tesla himself correctly explained in a registered invention for collecting the high voltage charged ions the sun bombards the earth with everyday! his electric car that had nothing to fuel it but an 2 meter antenna extending 1 meter above the car top picking ambient electrical radiation energy (coming from the sun) leaking through the earth's magnetic shield through a process called magnetic re-connection observed frequently by a European space probe and considered to be a permanent and significant phenomena by the scientists using it!

MQ 11/17/2015 06:52:13 am

You are right. But Tesla's electric car had nothing to fuel it but a 2 meter antenna picking ambient electrical radiation energy (reaching us from the sun's electrically charged ions radiation leaking through the earth's magnetic shield through a process called magnetic re-connection observed frequently by a European space probe and considered to be a permanent and significant phenomena by the scientists using it!

REPLY

Clay king 7/10/2015 09:37:26 am

He is right, kinda of . It does work,and it is easy. But not quiete

REPLY

Clay king 7/10/2015 09:49:19 am

Interrupted, sorry. It works, anybody a do it. Most of you already own the parts. It is not rocket science. You can't make money off it it is so easy. Violates no laws. Your all just lazy. Read, read, read, read. If your lazy you won't find it. When you do, you won't share it with other lazy people. Just pisses you off. Just tell them troll forums or watch more football.
It works
Get off your butts.
Or
Watch more football
By the way the world IS really flat.
Good luck to the diligent
The rest of you can watch more football

REPLY

Clay king 7/10/2015 09:50:32 am

It works

REPLY

Captain_Obvious 10/28/2015 07:22:17 am

Show me.

REPLY

Mr E! 8/15/2015 07:45:21 pm

First

THANKS for such an awesome, well written article. I love the way you avoid all the techno babble and speak plainly! Thanks also for including pictures and diagrams. This helps immensely! This is exactly what I wanted to move forward. The author is both brave and brilliant!

Second!

Kudos to Clay King! You are the man! And you are correct! Thanks for your encouragement!

Third!

Anyone who wants to enjoy this technology successfully would do well the heed Clay's words. Though my engineering training taught me most of this is impossible, I can tell you first hand that I have seen and benefited from related technology! It is REAL and it Works!

The way I moved forward in understanding and using much of this stuff was from forums like this.

My formula for succeeding to this point is something you may want to utilize. It is to.....

A) TOTALLY IGNORE ALL THE NEGATIVE PEOPLE AND COMMENTS STATING IT WONT WORK! Some of them are paid to be on forums like this to discourage you, distract you, start arguments with you, and LIE to us!

B) Carefully assemble parts and run my own experiments with SAFETY FIRST in mind. It is a good idea to keep one hand in your pocket when testing live circuits in case of an electrical shock. It is a simple way to prevent the current from having a direct path across your heart. Not foolproof. But is has saved me a few times.

Encourage one another and share whatever successes that you feel comfortable sharing.

Don't waste your valuable intellectual energy arguing with nay-sayers! Just do your thing and work your experiments. YOU WILL SUCCEED!

Be aware that many people have succeeded in replication and even innovating above what Tesla gave us. (Check out John Bedini).

However those who succeed are sometimes reluctant to share everything with you out of fear (real or imagined) of being harassed, murdered etc. (Stan Meyer, Jim Watson, et. al.)

MOST IMPORTANTLY put what you learn to practical use! Even if it is in a small way. For YEARS I stuied alternative energy, and experimented, and even did not believe what I ws seeing happening to the point that I did not use it.

Then one day I decided it was real and found ways to use it. Through conservation and alternative energy I say my electric bill drop for $300.00 monthly high to $90.00 monthly high with an average of $52.00 a month! (tesla inspired Bedini devices and such)

I saw my gas mileage on 1994 Nissan go from 19 MPG to 34 MPG. (HHO)

Best of all was the sense of pride in learning and using these things after throwing off the shackles of so called "Laws of Physics" "Conservation of Energy" "conventional electrical theory" Certainly these things have their place. In my opinion they are only a basis and not written in stone.

And whenever I see my success go against these concepts, then I adjust my understanding accordingly. This took nearly six months or more for my mind to accept and for me to get off my butt and actually put it all to use!

I had to UNLEARN much of what I had been taught! Trash conventional dogma and reap benefits of more freedom and prosperity.

I still have much more to learn, and these writings and diagrams on this forum are a serious help!

Personally, I also suggest forget about making a gazillion dollars from this technology by marketing it conventionally. Nor challenge others to do so. Nor wait to see it in your local car dealership or hardware store.

If you want it, and do not have it, get off your own butts and make it happen! The sooner you start, the sooner you can enjoy it!

Just Do It for yourself and enjoy the benefits.

If you want to really change the world for the better. Then share your successes freely via the internet, improving lives here and there. Once it goes totally viral, then contact Oprah (or the media at large) with your documentation in hand proving you are the one who has been successful with this and submitting it to others.

You will become the media darling of the new millennia and command high prices for touring and speaking engagements.

Of course you can also put up an educational website giving away the information freely and asking for donations!

Or you can just let PRIDE be your payment, knowing you have helped create a better world for us all!

To all of you I say, stay encouraged, TURN OFF THE T.V., use what you see here as a starting point and get to building and testing.

God bless you all, I love you much!

REPLY

Captain Obvious 8/16/2015 12:14:02 pm

Too bad you can't feed enthusiasm into your generator.

You can burn bullshit, though, and heat water with it. Free energy!! Oh wait, how much is your DVD and where can the suckers send money to get it??

REPLY

The Shining One 1/23/2016 11:56:38 pm

Thank you.

REPLY

Captain Obvious 1/24/2016 04:59:35 pm

You're welcome. BTW, Bedini is a scammer. So was Stan Meyer. They are "persecuted" because they have cheated people.

Me 2/2/2016 11:20:10 am

First thing I will need is a tin foil hat. Do you plans for one?

REPLY

Mr e 8/19/2015 06:17:13 pm

PROFANITY IS THE STRONGEST EXPRESSION....OF A WEAK MIND!

Both of these truths are self evident from all your postings.

I encourage others without selling them a DVD because nobody sold me a DVD in order for me to prosper with the aforementioned technologies!

And I am truly thankful for the author of this website and the others who are positively contributing. I already have purchased an ignition coil and have other relevant materials on the way.

You see, My parents were into engineering and education and insisted that their offspring make learning a lifelong endeavor!

So YES! This technology REALLY does work and not all that hard to

I just had to turn off the TV, open my mind, study, experiment, apply what I learned!

Of course I also had to ignore people with negative attitudes, and not give them my valuable time. I make one exception, then if they continue to be negative I do not answer them. My life is too much fun for me to waste it on downers.

The Savings from this technology helped to pay off my mortgage too! Paid CASH for the last 2 cars I bought as well. AND RETIRED early! I now "work" for fun and still get paid a lot of money!

Amazing what you can do with the money you save when you aren't paying high utility bills and gasoline!

However I firmly believe in "to each his own way!"

If you like paying high gas and electric bills then go right ahead.

Whatever you do or say has no effect on myself or any positive thinking intelligent person anyway.

I do wish you well though, and God Bless!

REPLY

MU MOTO (http://mukulia-motors.webstarts.com) 10/27/2015 07:19:59 pm

i can build these boxes for @ $9999. to work harmoniously with any electric motor. they ARE NOT FREE. they are made of expensive components... and my engineering time is expensive. some of the components will wear out quickly and need expensive replacements.

the working device will TAKE energy from the atmosphere (not free) some part of space will be missing it, but NO COST to owner of power box. its hookup to motor replaces current contoller but proprietary connections are basically similar.

entire box including 9 supercapacitors weighs 27 pounds.

will only build 99 per year

REPLY

Captain_Obvious 10/28/2015 07:39:55 am

I have measured the radiation from the sun at 1.3 GHz. It is about 70 degrees Kelvin, which is noticeably above the cosmic background radiation or the earth radiation due to temperature.

I had to use a 30 foot wide reflector antenna to do it. I was measuring the pattern to make sure the radar's coverage was just above the horizon.

The power received from this large antenna at microwave frequencies is below a microwatt. Since the sun is so hot, the EM power radiated peaks out in the visible light, not at microwave or RF frequencies.

I suggest you use this power peak instead of trying to find power where there isn't any.

REPLY

> **MQ** 11/17/2015 07:12:26 am
>
> Your had the wrong test gear and phenomenon to check! It's the solar wind very high voltage electrically charged ions that are "mostly" deflected by the magnetic shield earth. It's extremely high that if only a tiny percentage of it leaked somehow (I'll explain immediately) that it will be enough to power every machine, car or plane as Tesla himself stated.
>
> The electrical radiation energy is leaking through the earth's magnetic shield through a process called magnetic re-connection observed frequently by a European space probe and considered to be a permanent and significant phenomena by the scientists using it!
>
> REPLY
>
> > **Captain Obvious** 11/17/2015 02:01:42 pm
> >
> > The problem is collecting enough of it to do something. There have been solar wind "propulsion" systems proposed, but you need a humungous sail and you don't get a lot of acceleration, but the good thing is they don't use propellant or power.
> >
> > And while that works in space, you don't get enough power to run a decent size satellite, TV broadcasting for instance. They all use solar panels, which are higher power density.
> >
> > Now, you could power everything on earth with a small percentage of the surface covered in solar cells. And we might just do that. so why can't you just cover the roof of your car and power that? Well, you can. The problem is how much energy you gather relative to how much the car uses. You can look up the power requirements of say a Nissan Leaf versus the power output of a single power panel, which will fit on the roof. This exercise is left to you. How long will you have to let it sit in the sun to get a certain amount of driving?

Turbinetech (http://Alternative news/ Forum) 1/24/2016 02:10:02 am

I really enjoyed all the view's and they were very educational, I am no expert in the field of electronic's or physic's I am a millwright/mechanic I have almost 50 years experience. I am working on a electromagnetic engine that is piston driven also a rotary version. I built my first motor from a single cyl. Briggs&starting it worked well enough to move on with it I'm using 12v electromagnets with reversible polarity for a push pull system. The push at the top of the stroke and pull (attract) for the return stroke so as to produce power both ways. I'm using modified sealed bearings o the crank so as to minimize the need for a lubricant. The only part's of the motor that move's are the crank and piston's. I would like to hear some input positive or negative it all helps in the end. Thank's to all

REPLY

Aaron 2/3/2016 03:47:31 am

The big question for me is with a small power source how to do make an 80HP AC motor run? How to you increase the Amps and Volts to run the motor properly.

You dont need an antenna in the sky to produce a small energy source. Why not just use solar panels. Im this age we have flexible panels that can be moulded over your roof. So again how can you increase your volts and amps to run an electric motor.

Im am not interested in "free unlimited energy" or perpetual motion just increase efficiency.

REPLY

> **Captain Obvious** 2/3/2016 10:20:45 am
>
> Very simple. 80 HP is about 60 kilowatts. Comeup with that, and you're good to go.
>
> However, you don't need a continuous 60 KW to run a car; you can get by with a lot less for constant speed travel. Just overcome wind and friction. That's the principle behind hybrid drive systems. You store energy in a battery, using it to accelerate, and store it regeneratively on deceleration.
>
> Unfortunately, the amount of solar power on a small area is not high enough to power a big heavy car with accessories. You can run an extremely lightweight car at low speed, but even 100% efficiency is not going to run a Pierce Arrow with the A/C on. And solar energy is higher than anything else that can be picked up with an antenna.
>
> Cover your garage with PV panels and charge your car, and you'll get a few miles for "free".
>
> REPLY

Jon Bacha (http://3dage.net) 11/12/2016 02:07:06 am

solar could give a basload power of 1KW to charge battery or series of them,
a tripple phase electric motor could run on 3 legs of oscilating current at much lower amperages, So 3 x 12 volt DC lead batteries could out put enough horsepower to move the vehicle but only after coasting down hill but to accelerate would take a significant capacitor to crank up the output to voltages that would near the 150 N *M force out of the 90 horsepower motor. So some how amplifying 1 kw of power 90 times to get speed up to a
momentum of a steel car that could sustain the velocity with little added acceleration from the electric motor. Energy expended during the inital 5 ramp up to 90 mph would be in the neighborhood of 300 sec x 60 kw = 1,800,000 Joules. A sla Battery may have specific energy 12v x 500 amp
for a short impulse may output only 2,000 watt x60 Sec = 120,000 Joules
So a Magnifier of at least 10 to get close to the 1 M J needed to reach 90 mph. If a alternator could conected to drive shaft and engaged when going down hills every mile could charge the battery for 1 min with 12 Vdc x 100 amp : 1200 watts for 60 sec = 60,000 joules, possibly the electric motor could also regenerate a charge with a rectifier circuit. say another 100,000 joules. Tesla must have been way ahead of the current tecnologies in energy recovery from electric motor. So when the car stopped for the day it took the night to recharge the battery. :)
The limiting factor is the capacity of the SLA battery 12 more needed with a depth of discharge of 30% . Then it may only run for a hour depending how many hills he could coast down.

REPLY

> **Captain Obvious** 11/14/2016 02:52:56 pm
>
> Yes, that's right, all you need is a gadget to multiply energy. Come up with that, and you will get a Nobel Prize in physics and solve the energy problem forever. The naysayers insist it is impossible, so here's your chance to prove them wrong. Tesla used the term "amplify" not to refer to free energy generation, but to control of existing energy.
>
> 1KW is a bit more than a horsepower, which would keep the air conditioner running on a modern Pierce Arrow or propel it down a level road at 25 MPH or so. All your schemes of saving power in batteries have a problem of not "amplifying power". You can't use regenerative braking and get more than what you put in.
>
> Your idea of recharging the batteries at night would work great if the sun shone at night. Otherwise you'd have to do what every Tesla and Leaf driver does, and suck it out of the power grid while you sleep so you can drive to work in the morning.
>
> REPLY

Captian not so obvious 6/20/2017 12:06:21 am

OK, I am not an expert in this but here is a theory...

If the radiation you are tuning into and collecting is super high frequency, and the frequency you need to power your device is much, much lower but you need a larger volume of energy, wouldn't is be plausible that if you were to somehow transform that energy through a step down transformer, couldn't you tap into this aether?

REPLY

> **Captain Obvious** 8/9/2017 10:16:59 pm
>
> No, you are not an expert.
>
> The basic problem is the amount of energy. If there was enough, you might be able to construct a device to transform it into a usable form. But, there isn't. Electricity floating around in the wind would require large collector antennas, and yield minimal power. Remember, voltage is not power.
>
> You are better off putting up a windmill and solar PV array and charging a battery.
>
> REPLY

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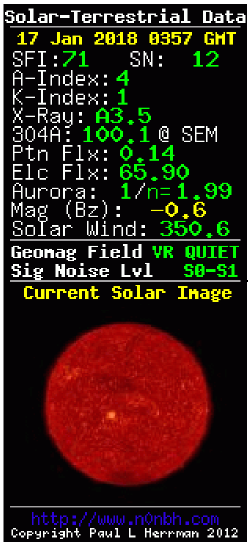

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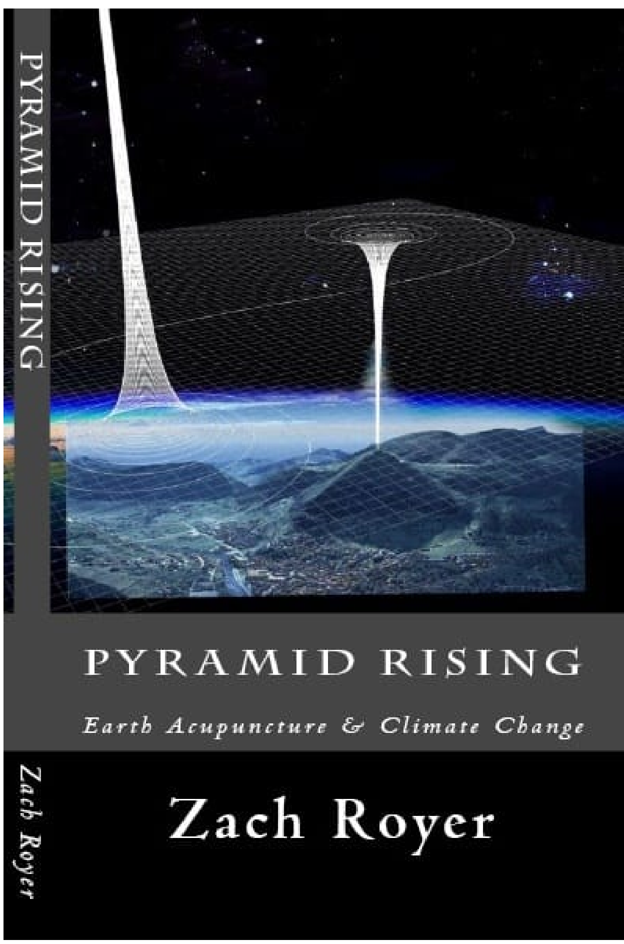

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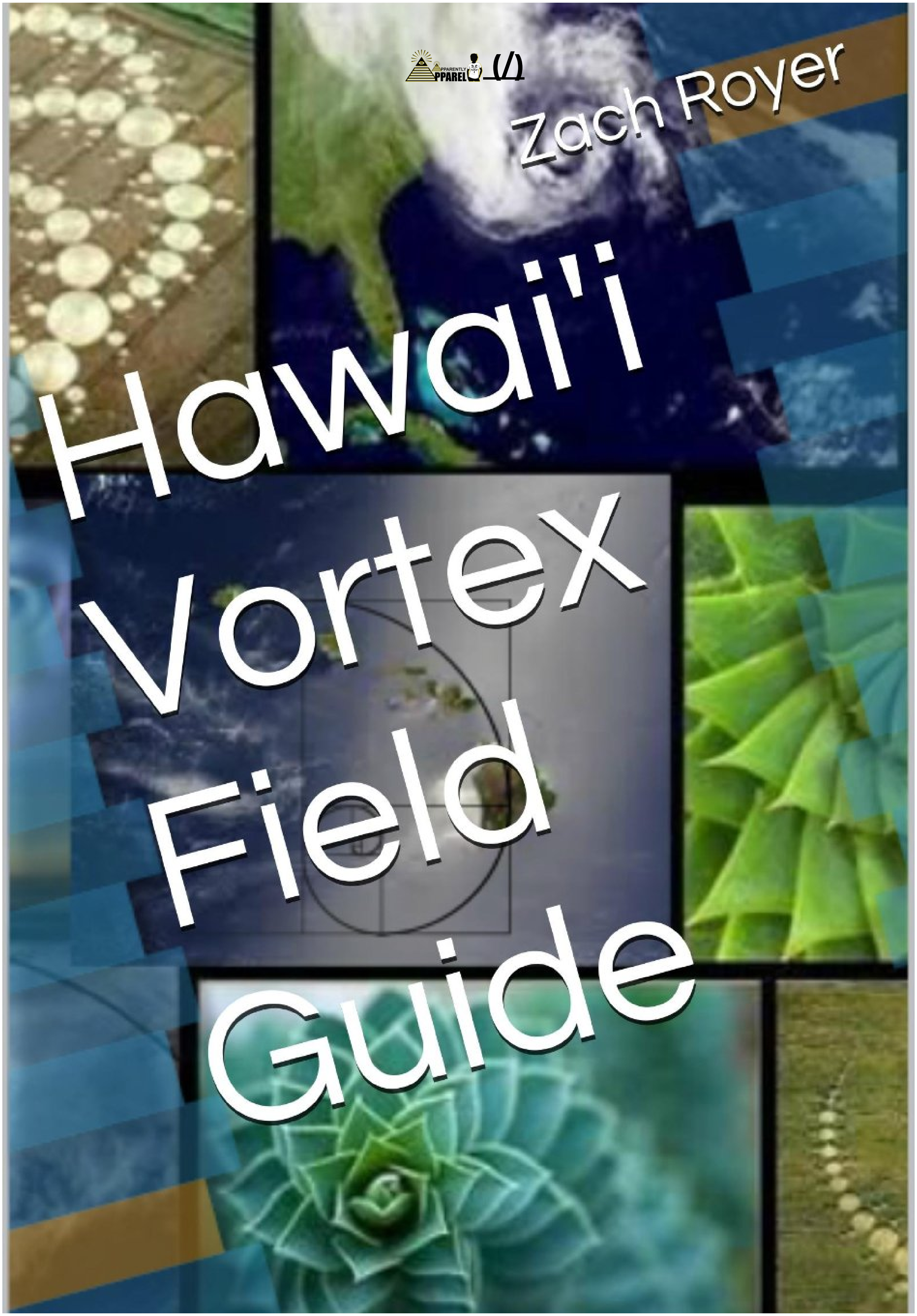
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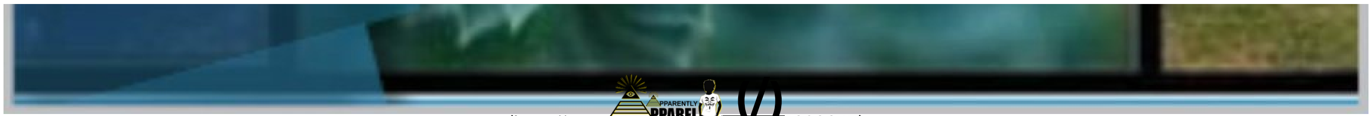

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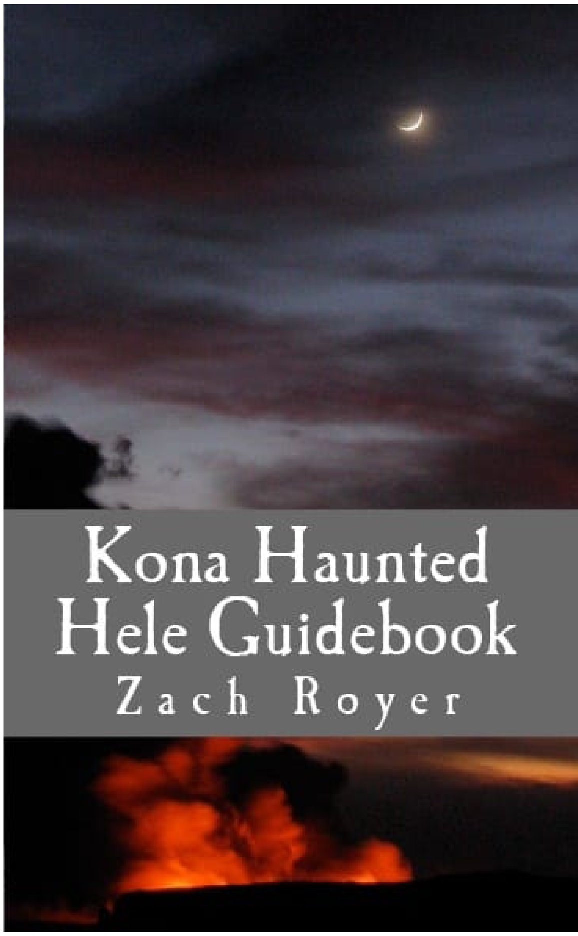

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Practical Circuit Board Construction

Ian 'at-play' with a design under construction.

Ian Liston-Smith has a technique for producing circuit boards for his projects, that look like p.c.b.s, but doesn't use chemicals.

For many decades now the printed circuit board (p.c.b.) has replaced all other assembly methods in the manufacture of electronic goods. But for reasons I have never understood, radio and electronic hobbyists try to emulate this construction method. And why is this you may ask?

The p.c.b. was specifically designed for mass production and I think it is therefore singularly unsuited for the home constructor, unless of course it is provided as part of a kit. When the task of making an individual p.c.b. is well done, the enthusiast can obtain a professional finish.

Making a one-off p.c.b. is a method that is mostly time consuming, inflexible and requires the use of some often unpleasant chemicals. Fortunately various alternatives for creating p.c.b.s, are available in the form of copper strip matrix boards.

Matrix boards with fixed copper strips have two significant disadvantages. Often an awkward component layout is required. The resulting redesign of the layout, for anything other than a simple circuit, can take a considerable time to rework.

Many matrix boards are not generally suitable for circuits operating above medium frequency r.f. or the lowest of the h.f. Amateur bands, due to their lack of earth plane and stray capacitance between the strips or pads.

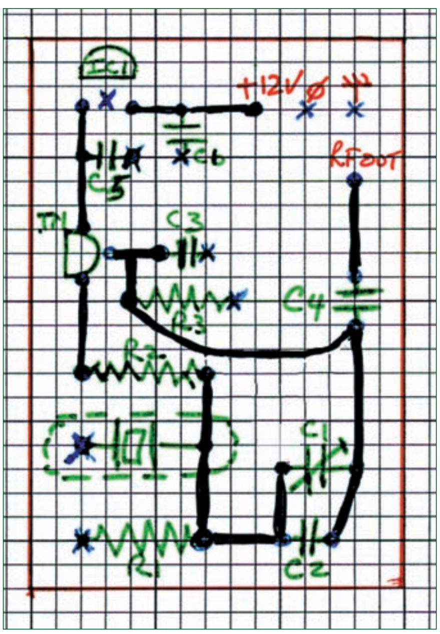


Fig. 2: If there is no circuit layout in the magazine article, then sketch one out, on squared paper, as shown here.

Dead-bug

The technique of construction, often called the 'dead-bug' (so called because of the look of some of the components) is another favoured construction alternative. This is a method that uses a single sided p.c.b. material board as the earth plane and 0V rail. *(If you're still unsure, have look at many of the smaller projects produced by **George Dobbs G3RJV**. It's a method favoured by many other members of the G-QRP club.* Editor)

In many instances, when using the dead-bug method the major components, such as integrated circuits (i.c.s) are glued to the copper clad material, which gave rise to the characteristic look of dead bugs with its legs in the air! The other components are soldered to each other or the copper earth plane.

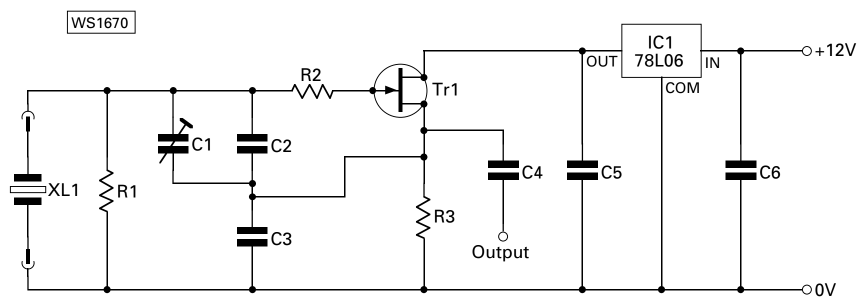


Fig. 1: A simple crystal oscillator circuit used to demonstrate the technique presented here.

The dead-bug method, favoured for many of the simpler projects, is ideal for prototyping. It's a method I often use, although I think it tends to look rather too messy for the finished project.

Island Matrix Technique

Another alternative method of construction is the 'island matrix'. This is another interesting method, using very small squares of board, cut out and glued onto a much bigger board of p.c.b. material.

However, the island technique doesn't provide a neat finished layout either. The capacitances formed between each of the islands and the main board also rule this system out for many r.f. projects, except those at the low end of the spectrum.

I was looking for another way - one that combines the ease of production of the other methods, but has a more professional finished look. The method described here is the one I have settled on. I doubt my method is original, but I now use it for all my projects.

In my method, the components are mounted on the upper side of single sided board and the leads pass through countersunk holes and are then wired up underneath. I'm sure that purists would say that this strictly speaking isn't a p.c.b. However, it combines the best of both worlds.

It's a system I have not seen described by anyone else (although years ago I did briefly describe it elsewhere). It's a method that is at least as easy as the alternatives with the following advantages:

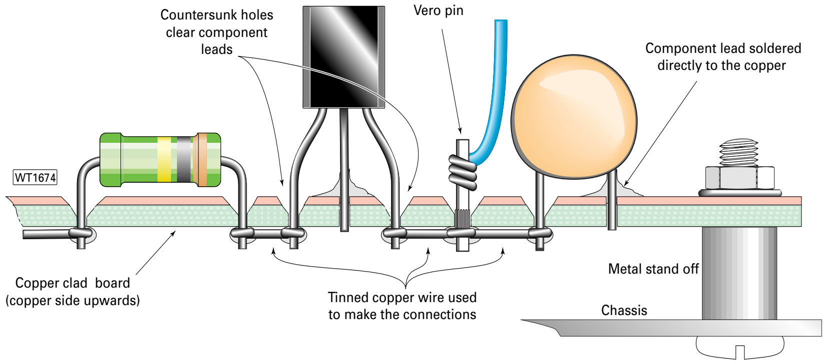


Fig. 3: A cross section through a typical board design, just to illustrate the technique of linking components together.

- No etching chemicals are required.
- The upper copper side acts as the earth plane and this is particularly suited to r.f. circuits, although it works equally well for power supplies, audio, digital circuits etc.
- Suitable for the novice or experienced constructor.
- Can easily be modified to accommodate circuit alterations.
- The finished appearance is that of a real p.c.b.
- If a project has a p.c.b. layout, this can be used. The wiring underneath then follows the track design.

Crystal Oscillator

The example design described here shows how a crystal oscillator is constructed using this technique. The circuit is shown in **Fig. 1** and a sketched board layout in **Fig. 2**. But if there is a layout in the magazine article, then it would make sense to follow that layout, rather that redesign it for your board

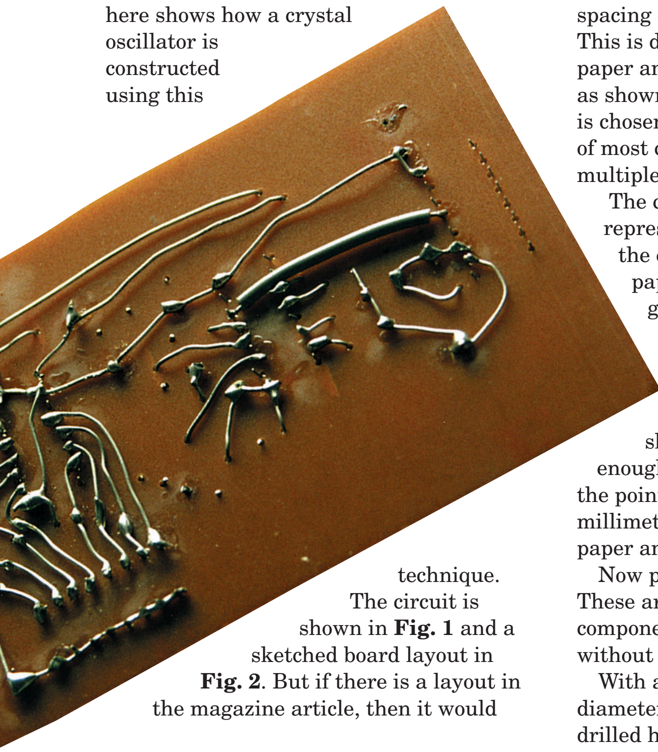


Fig. 6: The project of Fig. 5, but this time from below!

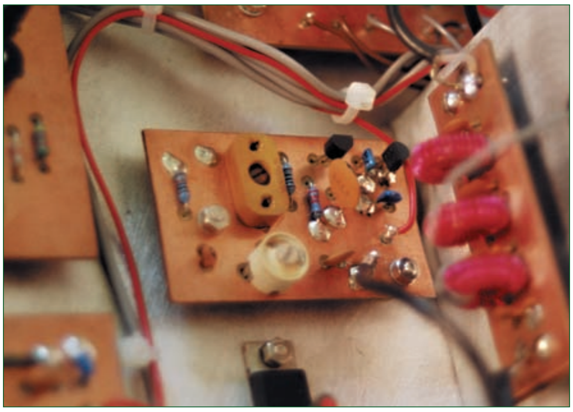


Fig. 4: The finished board in place in the full project.

The Method

Collect all the components for the circuit before starting so, that lead and component spacing can be worked out. This is done on 0.1 inch graph paper and drawn actual size as shown in Fig. 2. This paper is chosen because the spacing of most component leads are multiples of 0.1 inches.

The crosses in the layout represent earth points on the copper side of the board. When the paper layout is completed (allowing gaps between some components for the mounting screws), cut it out and tape it over a piece of board of the same size, copper side up.

With a centre punch or other sharp instrument, press hard enough to make a good indentation at all the points marked with dots. Using a one millimetre drill bit, drill right through the paper and board at these points.

Now press to mark all the X-points. These are the holes for the earthed component leads. Remove the paper without drilling these.

With a Verocutter or six millimetre diameter twist drill, countersink all the drilled holes. These are the holes the component leads must pass through without touching the copper surface.

Now drill through all the X-points. Doing it in this order prevents the X-points from being accidentally countersunk.

There are likely to be minute pieces of copper around the countersunk holes that could short out components later. To clear these, rub the whole board with emery paper or coarse wire wool. This will smooth the holes and polish the copper ready for soldering.

Finally, to remove all the debris that will now have got pushed into the countersunk holes, gently go over them again with the Verocutter or six millimetre drill. The board is now ready for the components.

All components requiring an earthed connection have the appropriate lead soldered to the top as shown in **Fig. 3**. Veropins are used for test points and any flying leads. Tinned copper wire is used to connect the components together under the board. If the layout is cramped, slip an insulated sleeve over any wires running close to each other.

Drill holes for the M3 mounting bolts between the components. These will provide a good earth to the main chassis. The board is held above the chassis with plastic or metal spacers. As you can see from the photographs of finished item in **Fig. 4**, the end result is very neat and professional looking.

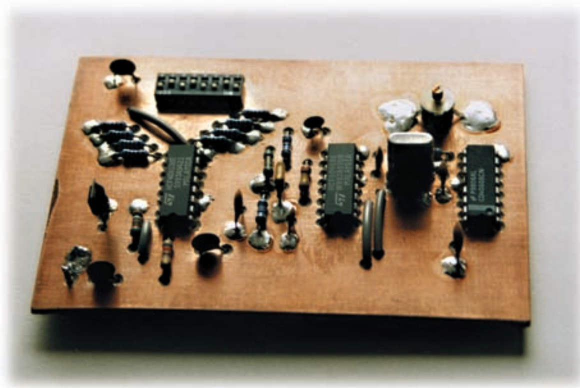


Fig. 5: A rather more complicated layout from above...

More Complicated

It's possible to create rather more complicated circuit layouts that the design I've chosen here to demonstrate the technique. A much more complex circuit using i.c.s and switches (see photographs) illustrate the flexibility of this assembly technique. Have a look at the photographs of **Fig. 5** and **Fig. 6** to see the design. I'm sure you'd agree that from the component side it's difficult to tell that it isn't a well made amateur p.c.b.

No one would know it wasn't a real p.c.b.! PW

RCA MI-7015 Direct FM Modulator Exciter

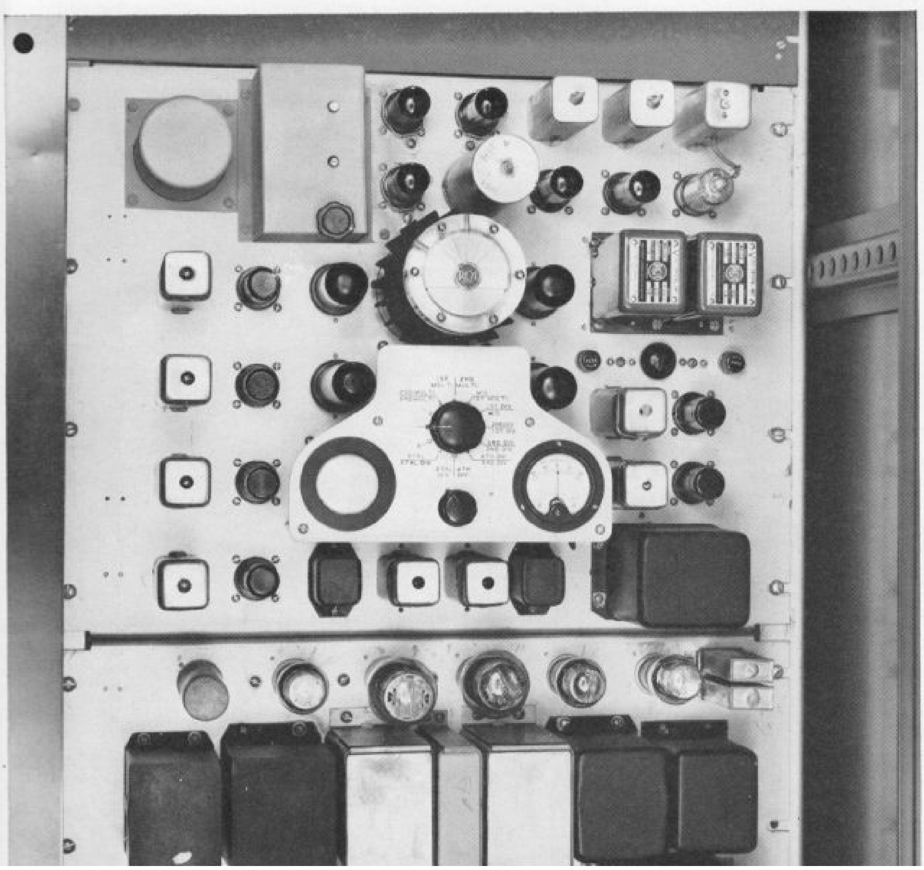
This article was published by RCA in Broadcast News, Vol. No. 42, January, 1946.

A NEW FM EXCITER UNIT OF GREATLY IMPROVED PERFORMANCE

by N. J. OMAN
Transmitter Engineering Department
Engineering Products Division

An Exciter Unit of entirely new design is a feature of the new line of RCA FM Broadcast Transmitters and is used in all of the new models.

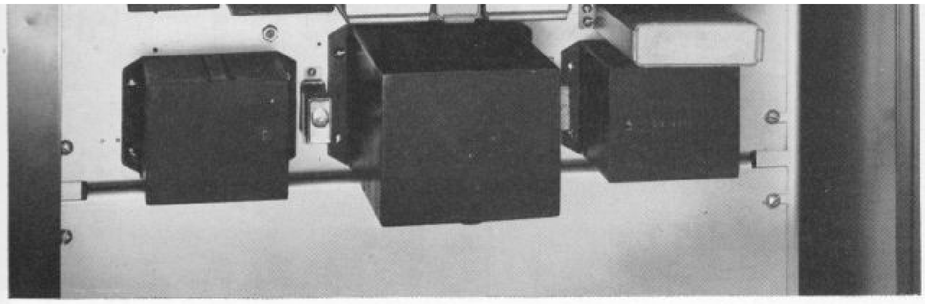
Mechanically, the new Exciter consists of two vertical panels, as shown in Figure 1. One panel contains the r-f and modulator circuits and the other the regulated power supply. These panels are mounted in one of the standard cabinet units of which all of the new FM transmitters are made up. The construction employed in the units themselves provides a degree of accessibility seldom realized in this type of equipment. All tubes and main components are mounted on the front of the panel. Wiring on the rear of the panel (Figure 2) is "in the clear" with all terminals clearly marked and easily accessible. Doors on the front and back of the cabinet provide quick access to either side of the panel.



In the transmitters of 3 KW and higher power ratings, space is provided for permanent mounting of an additional Exciter Unit; thus providing a spare which may be quickly cut-in in case of failure. If it is desired to provide a "spare" unit with the lower power transmitters, an additional cabinet unit can be furnished which may be used to house this and other accessories.

Electrically, the new Exciter includes all of the frequency generating, modulating, and frequency multiplying circuits of the transmitter (except the final doubler). A new and greatly improved form of the *direct FM circuit* developed by RCA engineers is employed. Features of this new design include:

(1) Simplicity of reactance-tube modulation system.
(2) Crystal-controlled frequency stability.
(3) Distortion of less than 0.5% through entire range of 30 to 15,000 cycles.
(4) Stability independent of circuit adjustments.
(5) Frequency dividers of relatively high ratio and simple design; thus fewer tubes and circuits are required.
(6) Only crystal unit is temperature controlled.
(7) Every component and connection is easily accessible.
(8) An ingenious built-in checking device which includes everything necessary for checking performance of fre-



quency control circuits, frequency multipliers and reactance modulators.

In evaluating the importance of these features a discussion of the development and operation of the circuits used in the new exciter should be of assistance.

FIG. 1. *Front view of the new-type exciter unit used in all of the new RCA FM Transmitters. Other photos of this unit are shown on pages 11 and 14.*

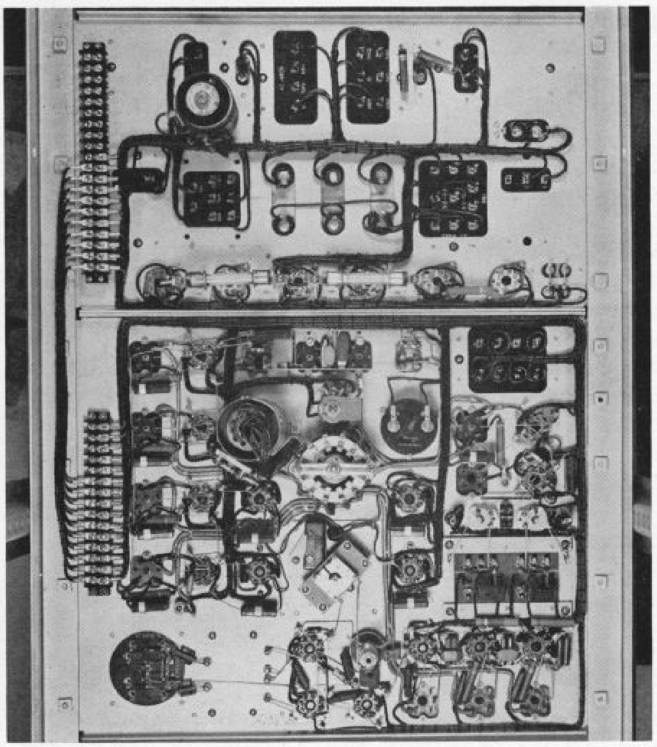


FIG. 2. *Rear view of the new exciter unit. All the wiring is 'in the clear" and all terminals are plainly marked for easy identification.*

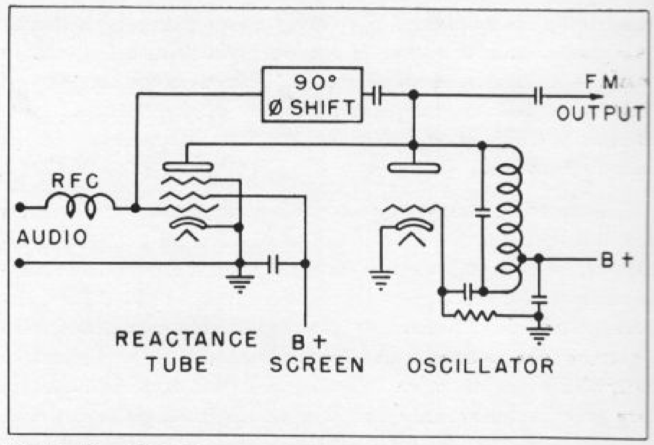


FIG. 3. *Simplified diagram of the reactance modulator circuit developed by RCA engineers. This circuit accomplishes frequency modulation directly without need of trick tubes or circuits.*

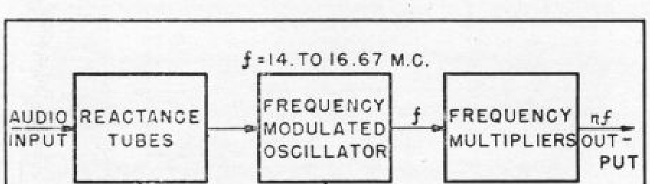
ADVANTAGES OF "DIRECT" FM

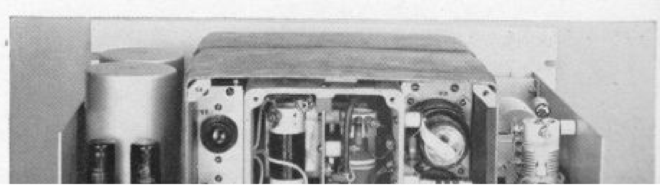
A good exciter for a frequency-modulated transmitter should be capable of producing a variation of frequency about a mean frequency in very exact duplication of the program material. In addition, the stability should be such that any shift in frequency is in response to signal voltage and nothing else; thus, when modulation is not present, the frequency will be the exact center of the band assigned to that particular broadcast station.

There are a number of methods of producing the desired frequency modulation. These are generally classified under two headings—"Direct" and "Indirect." The Direct method, developed by RCA engineers, uses fewer tubes and introduces less audio distortion (especially at extreme high and low frequencies) than the Indirect method. In this system the mean or "carrier" frequency is produced in simple and straightforward fashion by a master oscillator, operating at a medium frequency, followed by a relatively small number of multiplier stages. Frequency modulation of the master oscillator is accomplished directly by means of a reactance tube modulator. A simplified diagram of such a system is shown in Figure 3. With this arrangement a change in voltage on the grid of the reactance tube causes a change in the reactance which it places across the *tank* circuit of the oscillator, and hence a change in the oscillator frequency. When an audio modulating voltage is fed to the grid of the reactance tube the frequency of the oscillator is caused to vary in exact accordance with the modulating frequency. This is unquestionably the simplest method of producing high-fidelity frequency modulation.

THE PREWAR MODEL

In the past the problem with the Direct FM circuit has been that of compensating for the drift in frequency of the master oscillator. The RCA prewar FM Exciter (Figure 4) accomplished the frequency regulating function by beating the master oscillator with a signal from a crystal-controlled oscillator to produce a beat note at approximately one megacycle. The fluctuation in the one megacycle frequency caused by variation of the master oscillator frequency was converted to a varying d-c potential by





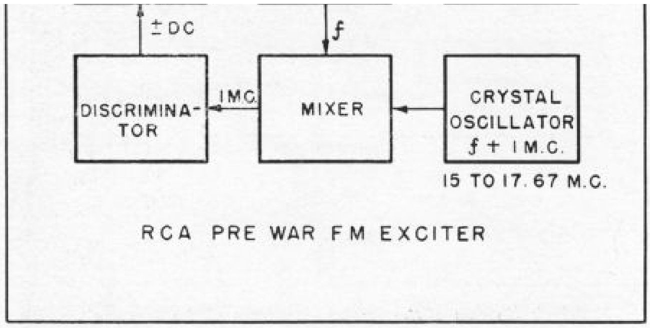


FIG. 4. *Block diagram of the RCA prewar FM exciter (shown for purposes of discussion only).*

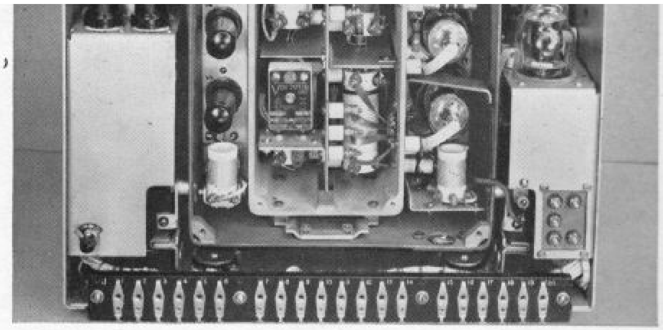


FIG. 5. *Rear view of prewar exciter. Comparison with Figure 2 shows advance made in mechanical construction and arrangement.*

means of a discriminator. The varying d-c potential so obtained was passed through a filter to remove rapid fluctuation, such as would be caused by modulation. The filtered Direct current was used to control the grid potential of one of the reactance tubes in such polarity as to reduce any change in frequency of the master oscillator.

This method of frequency control is very simple and its operation is easily understood. However, the d-c control potential is dependent on the discriminator characteristic; it fluctuates because of changes of contact potential of the rectifier required for operation of the discriminator. By placing the master oscillator, the reactance tube modulator and the discriminator in a temperature controlled oven, as shown in Figure 5, it was possible to obtain very good performance. From an operating standpoint, however, the oven tended to offset the desirable feature of circuit simplicity because it made access to circuit elements difficult and time consuming.

NEW METHOD OF FREQUENCY CONTROL

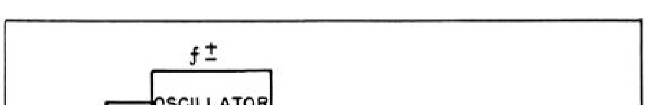
The new RCA FM Exciter has been designed to overcome these objections. As noted previously, all the parts are mounted on a flat panel with ample area so that they are readily accessible. The only temperature-controlled part is the crystal unit of the reference oscillator. The frequency control circuit adopted represents a considerable improvement over previous circuits of this type. In particular it reduces the number of parts and required adjustments. Another big advantage of the circuit is that no adjustment has any effect on the accuracy of frequency control.

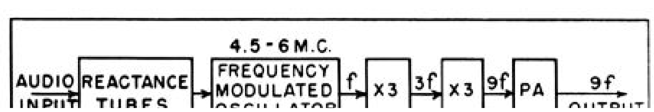
Referring to the block diagrams, Figure 6, the operation of the control may be described as follows: Two balanced modulators are set up to obtain in the output of each a beat frequency corresponding to the difference between the crystal reference frequency and that of the master oscillator. The signal output from the crystal oscillator divides and feeds through phase shift networks designed to give a 90° displacement in phase between the inputs to the two modulators. The signal from the master oscillator is of the same phase in both modulators. It is rather obvious that the 90° displacement in the crystal oscillator signal will result in a 90° displacement of the beat frequencies in the output circuits of the two modulators. Not so obvious, but nevertheless true, the direction of rotation of the two 90° vectors, that might be considered as generating the two-beat frequency outputs, changes from clockwise to counterclockwise depending on whether the master oscillator frequency is higher or lower than the crystal frequency. In other words, there is a reversal of one phase of the two-phase output of the two modulators when the master oscillator frequency passes thru zero beat with the crystal frequency. If the two-phase output of the two modulators is utilized to energize the field windings of a two-phase motor, the direction of rotation of the motor shaft will be clockwise if the master oscillator frequency is higher than that of the crystal oscillator, and counterclockwise if the master oscillator frequency is lower than that of the crystal. The motor can therefore be used to turn a capacity or other tuning means to effect a correction of the master oscillator frequency should it depart from that of the crystal oscillator. A preliminary arrangement of this kind is illustrated in Figure 7.

DIRECT MOTOR DRIVE

If the frequency control is to be a precision device the method of drive (or the mechanical coupling) between the motor and the tuning element is very important. It will be recognized that the system, as described so far, has a very desirable feature in that the rate of rotation of the free motor shaft would, within limits, be proportional to the difference of the oscillator frequencies, as opposed to an on-off device that would give full motor speed up to correct frequency. This characteristic of the system helps reduce difficulties with hunting so prevalent with automatic controls of similar type. In preliminary tests of this control a worm-and-pinion speed-reduction gear was used between motor and tuning condenser. This method of drive proved to be unsatisfactory. When sudden large frequency corrections were required, a relatively long time was consumed by the operation. For small frequency deviations the action was sluggish, since the motor turned very slowly. It had first to take up lost motion in the gearing and it had to develop enough torque to overcome static friction.

To correct the above-mentioned condition the tuning condenser rotor was mounted on an insulator on one end of the motor shaft. The fixed plates of the condenser were split in half, one half was grounded, the other half was connected to the master oscillator plate circuit (see Figure 8). This construction eliminates all backlash or lost motion, and also eliminates friction other than that of the motor bearings. With this construction the motor





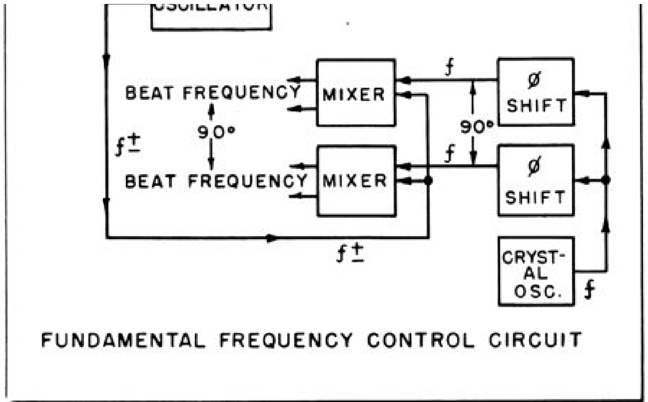


FIG. 6. *This is the basic control circuit used in the new exciter. Two beat frequency voltages, 90° out of phase, are used to drive a two-phase motor which controls the position of the frequency-determining condensor.*

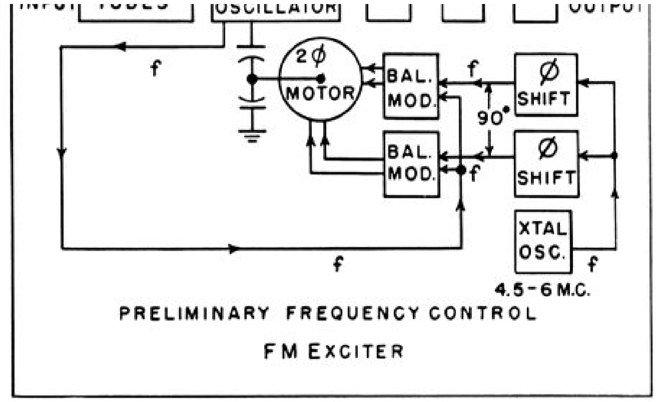


FIG. 7. *Block diagram of the preliminary form of the new exciter unit. In this arrangement the crystal-controlled oscillator operates in the 4.5 to 6.0 megacycle band, thus permitting direct comparison with modulated oscillator frequency.*

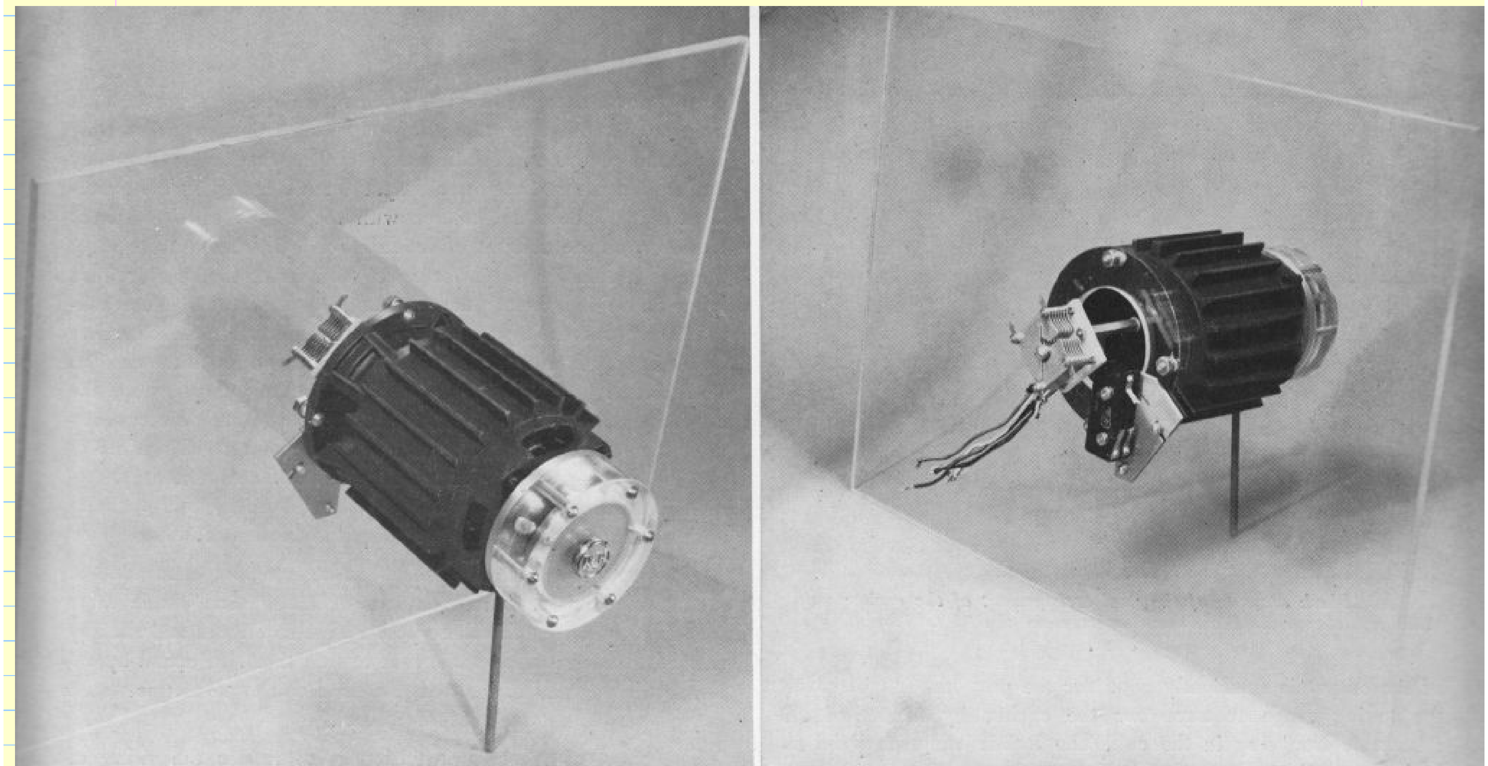


FIG. 8. *Front and rear views of the two-phase motor with the frequency-determining capacitor mounted directly on the motor shaft. On the front end of the shaft (enclosed in the Lucite case) is an oil dampening unit which prevents overshooting.*

is never required to turn more than ±45° to include the full range of control, and friction is reduced to a minimum. The action is fast and positive. The motor can easily follow the slightest variations in frequency. The rate of frequency correction is limited only by the requirement of not causing demodulation of the lowest signal frequency.

ADVANTAGE OF INDUCTION-TYPE MOTOR

Several types of two-phase motors were considered for the control. One was of synchronous type with a permanent magnet rotor. This motor provided very accurate control, but none tested would start if the initial frequency exceeded 60 cycles-per-second. No damping could be used with this synchronous motor and inertia had to be kept low so as not to hamper starting. A second

input and output waves, the output signal will appear only when an input wave is applied and bears a fixed frequency ratio with respect to it. The circuit makes use of copper oxide modulators and the output circuit is tuned to one-half the input frequency. The tuned circuits are made sufficiently broad to permit substantial output voltage over a frequency range of ±1.5%. The disadvantage of this circuit is the number of tubes and circuits required.

Another possible way to obtain frequency division would be to make use of multi-vibrators. The wave shape would be poor, but it would be possible to get higher division per stage.

LOCKED-IN OSCILLATORS AS DIVIDERS

The third circuit considered was the locked-in oscillator fre-

type tested was an induction motor. This had torque enough to start at frequencies up to 1000 cycles-per-second. Further tests with this induction motor, with viscous damper and direct-mounted condenser, demonstrated that it would respond to the slightest rotation of its magnetic field. This motor, therefore, was selected as most suitable for the control.

REASON FOR FREQUENCY DIVISION

Since the limit on the control range with this system is the high frequency response limit of the motor, an increase in the range of control can be obtained by dividing the modulated oscillator frequency, so that it can be compared to a crystal oscillator at a lower frequency. The range of control can thus be increased by a factor equal to the division in frequency. There are several ways of accomplishing the required frequency division. One is by the use of frequency dividing stages employing the principle of regenerative modulation, whereby a subharmonic is obtained by a modulation process. Since the output energy is obtained by a modulation process involving both the quency divider as shown in Figure 9. This circuit reduces the number of circuit components to a minimum. The wave shape

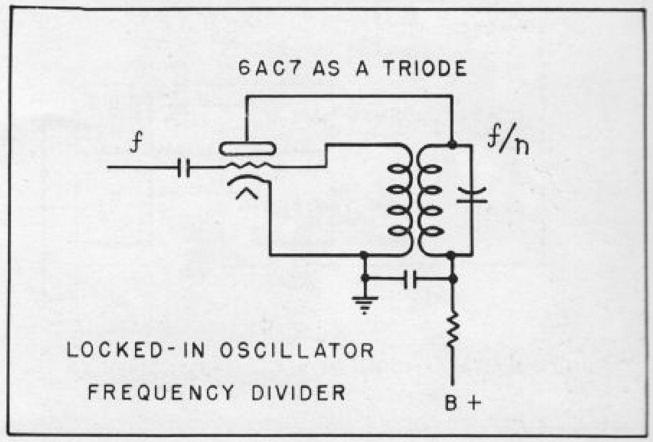


FIG. 9. *Circuit of the Beer's Locked-In Oscillator as used in the new exciter unit. This circuit permits division ratios of as much as five-to-one, thereby reducing the number of frequency divider stages which are required.*

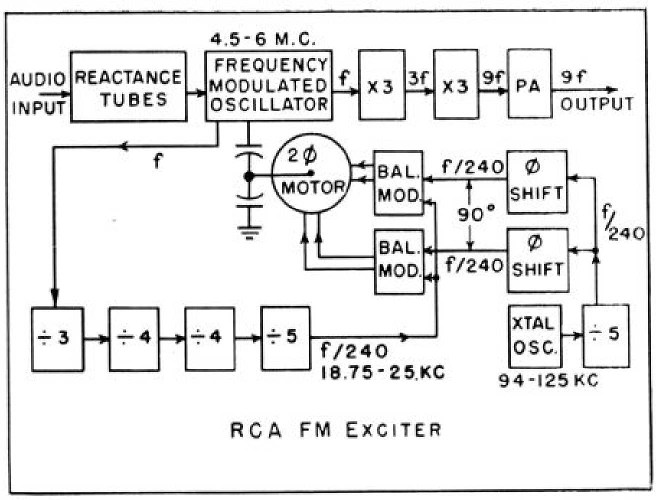


FIG. 10. *Block diagram of the final arrangement of the exciter unit. The crystal-controlled oscillator operates in the 94 to 125 kilocycle band.*

of the output is sufficiently good for the purpose. It will cover the tuning range required for the exciter by means of an adjustable iron slug in the coil. The lock-in range may be as high as ±5%.

FREQUENCY OF COMPARISON

Having selected a circuit for frequency division the next consideration was to fix the frequency at which the comparison of frequencies was to be made. During the war the RCA crystal group has developed a crystal and holder designed to operate in the frequency range of 90 to 125 kc. The performance of these units has been very good and they, therefore, were selected for use as a frequency standard for RCA postwar FM exciter.

A preliminary test of the performance of the frequency control with frequency comparison made at 100 kc gave excellent performance, except for loss of control in the presence of tone frequency modulation when the modulating frequency was below one hundred cycles. A fundamental characteristic of frequency modulation is that the power output (or the energy in the modulated signal) does not change with the degree of modulation. However, as the amount of modulation is increased from zero, there is a transfer of power from the carrier to the sidebands lying above and below the carrier frequency. This effect continues with increasing modulation until a point is reached where all the energy is in sidebands and there is no power in the carrier. With further increase in modulation, or frequency swing, the carrier again reappears. With the ±75 kc swing of frequency used for broadcasting, there are several cycles of this effect at low modulating frequencies. In early experiments where the frequency comparison was made at 5 mc (Figure 7) this phenomenon showed only as a loss of torque in the motor.

Theoretically we should have been able to find conditions of modulating frequency and degrees of modulation where there was no torque. Actually these points were so critical and sharply defined that it required some care to find them. In actual operation with program modulation, the condition of no-torque would not exist long enough to lose control.

The effect of frequency division is to reduce the swing of frequency with modulation, along with the reduction of carrier frequency. This is carried far enough (when the frequency comparison is made at 100 kc) that carrier loss occurs only at frequencies of modulation below 100 cycles and for 100 cycle modulation only with full frequency swing of 100% modulation.

This effect was not serious with program modulation, but in taking performance data on a transmitter with tone modulation it would be apparent. An additional division by 5. to 20 kc eliminates this trouble except for modulation below 20 cycles which is low enough to be neglected.

OVERALL CIRCUIT OF EXCITER

The final circuit of the new exciter is shown in this block diagram of Figure 10. The tubes in the top row are, from left to right, the reactance tubes, modulated oscillator, a frequency

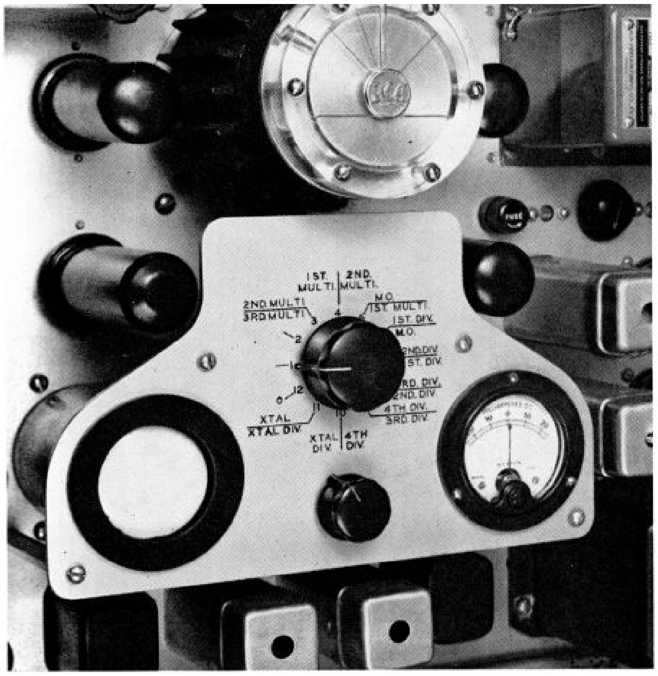


FIG. 11. *Closeup of the built-in oscilloscope checking device. The switch in the center is used to select the stage to be monitored.*

tripler, followed by a second tripler, and a power amplifier. The power amplifier is used to get sufficient power to feed through a transmission line to the main transmitter. The output frequency of the exciter will fall in the range of 40.5 to 54 mc. With a multiplication of two in the main transmitter a frequency range of 81 to 108 mc is provided.

A lead shown at the left in Figure 10 conducts synchronizing voltage from the modulated oscillator to the first divider at the lower left. The dividers are set up as shown with four stages, giving a total division of 240. This places the output frequency of the last divider in the range of 18.75 to 25 kc. The output of the last divider is connected directly to the two balanced modulators.

The crystal oscillator shown at the lower right may operate at any frequency between 94 and 125 kc. This is accomplished without the use of any tuning adjustments. The crystal output synchronizes a divider at one-fifth the crystal frequency. This frequency is also fed to the balanced modulators, but in this case a phase shifting network is included in the lead to each modulator adjusted to maintain a 90° displacement in phase between the modulators over the range of frequencies involved. The only tuning required in the crystal or reference frequency part of the ciruit is to set the slug in the divider so that its frequency is locked to one-fifth of the crystal frequency.

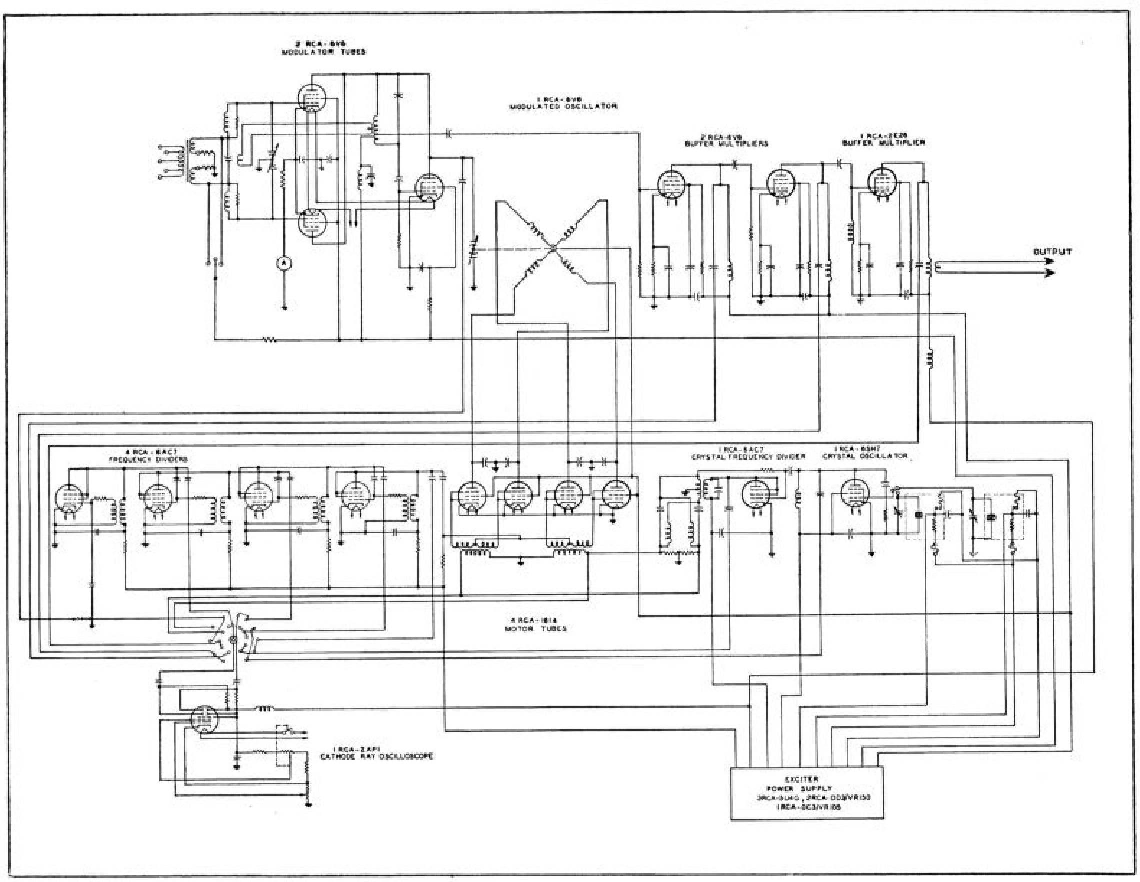


FIG. 12. *Schematic diagram of the new exciter unit used in all RCA FM Transmitters. Note that all tubes are of inexpensive, well-known types available everywhere. The circuits are simple and straightforward, easily checked. Only one crystal is in actual use, the second being a spare provided for emergency operation.*

OPERATION OF FREQUENCY CONTROL MOTOR

humidity or line voltage variation. The behavior of the frequency control motor and the relative rotation of the shaft required to

Each balanced modulator has a pair of 6L6 tubes biased to cut off and connected push-pull. The induction motor used has high impedance center-tapped windings on each phase so that it can work in the plate circuit of the balanced modulator tubes without the use of matching transformers. In this way the motor receives full voltage down to d-c beat frequency. The need for this is evident when one considers that the motor must respond to a beat frequency lower than one part in a million at 20 kc. This comes out to be .02 cycles-per-second or 1.2 cycles-per-minute. This rather surprising performance from an induction motor is largely made possible by the elimination of load on the motor. The absence of gearing and the use of viscous damping establish a condition in which there is little or no resistance to small or slow rotation of the motor shaft. The motor responds to frequencies up to 1000 cycles whereas the motors used in previous exciters of this general type were limited to 60 cycles, thereby requiring comparison at about 5 kc instead of the higher frequency.

BUILT-IN CHECKING DEVICES

The operation of the circuits may be checked easily and rapidly by means of test equipment built into the exciter. A cathode-ray oscilloscope, with a selector switch, is provided making it possible to check the operation of each divider and also the tripler amplifiers by means of lissagous figures. A three position selector switch enables the operator to apply a d-c potential to either reactance tube grid, causing the frequency of the modulated oscillator to shift high or low over a range considerably in excess of the range encountered due to ambient temperature control motor and the relative rotation of the shaft required to correct the artificial frequency shift may be observed on a dial on the motor shaft. This operation gives a rapid check of the performance of the reactance tubes and the frequency control mechanism. A meter is provided to read the plate current of the reactance tubes and the modulated oscillator. A buzzer, operated by a cam switch on the frequency control capacitor shaft, gives warning if for any reason the frequency control is about to fail because of passing through maximum or minimum capacity. The buzzer will sound only if there is maladjustment of oscillator tuning control or for the failure of all but a few of the frequency control circuit elements.

PERFORMANCE OF EXCITER

The accuracy of the frequency control is limited by the heat cycle of the crystal oven. On test this effect shows a regular variation of ± 40 cycles at 100 mc as the thermostat of the crystal oven goes on and off. The control action is smooth and rapid. There are no critical adjustments. The range of control can be as high as ± 1000 cycles at 20 kc or $\pm 5\%$. At 100 mc this amounts to ± 5 mc.

In case of failure of the frequency control during a program, operation can be continued with manual frequency control by locking the motor shaft and adjusting frequency with a vernier tuning control on the master oscillator tank coil.

The distortion in the frequency modulated output of the exciter is of the order of .5% for modulating frequencies from 30 cycles to 15,000 cycles. The noise level in the output is 74 db below 100% modulation.

4/25/10

John's Home Page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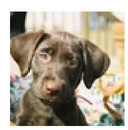
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Bio: I used to teach middle school science, but now I run my own online educational science website. I spend my days designing new projects for ... More » (/member/BrownDogGadgets/)

In honor of all my good friends still over in Japan I've decided to create an Instructable for a $3 Emergency Solar Radio. It's a great thing in case of tsunami, nuclear melt down, or zombie invasion. Plus it's really cute when put into an Altoids tin.

My plan is to send this as a (slightly) joke birthday gift to a good friend of mine living in California, who just so happens to be freaking out about possible nuclear clouds. This will also be really nice for her when she starts going camping again this summer.

The design is very simple and only takes about 45 minutes to put together, less if you know what you're doing.

If you'd rather not make one yourself, I'll probably be throwing up a couple completed ones as well as most of the parts over at my website BrownDogGadgets.com (http://www.browndoggadgets.com/).

Step 1: What You Need

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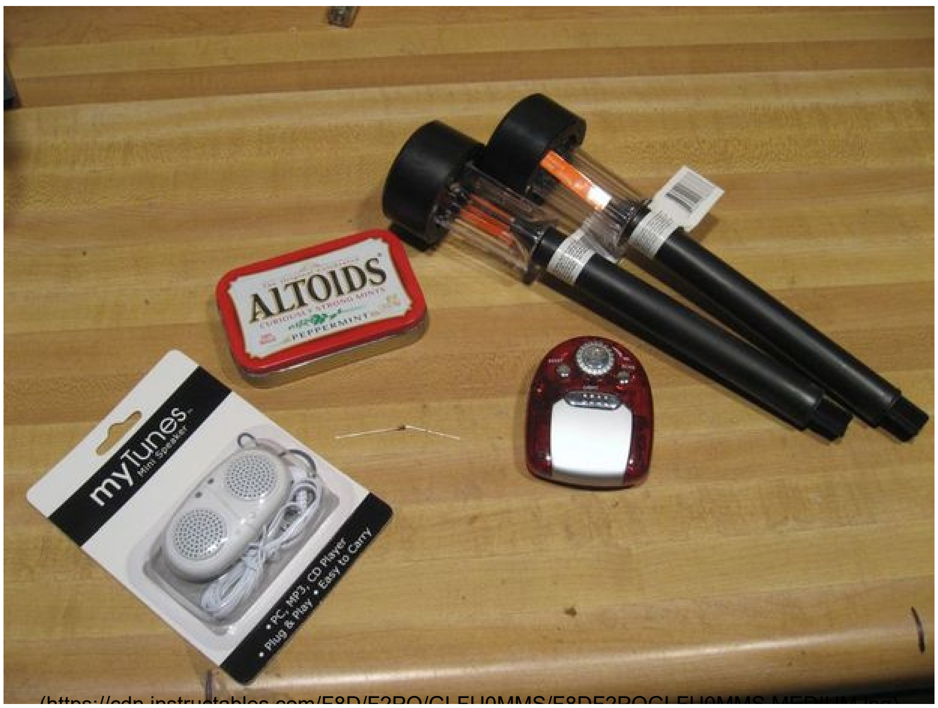

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I bought all the supplies I needed from my local $1 Store. (If in Japan, a 100 Yen store.)

To buy:
1x FM Radio
2x Solar Garden Light
1x Diode (http://www.browndoggadgets.com/collections/diodes) ($1 for 100 of them online, or take one out of any random junk pile)

If your local $1 Store isn't as cool as mine, you can probably find these things locally, online (like at my website BrownDogGadgets.com (http://www.browndoggadgets.com/)), or from a trash bin.

Tools:
Soldering Iron
Drill

Wire
Wire Strippers
Goggles
Tape

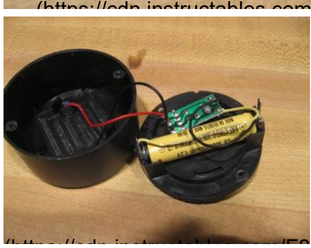
Optional:
Altoids Tin
Hot Glue
Mini Speakers ($1 Store, or take apart old headphones)

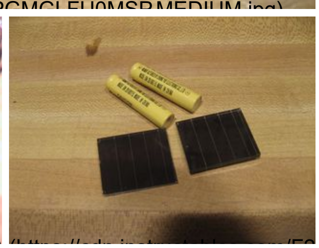
Support Me By Buying Some Parts...

If you can't find solar cells or cheap AAA batteries, I have quite a few on my website BrownDogGadgets.com (http://www.browndoggadgets.com/). The same solar cells I use to make my Solar Cockroach would work great for this project. You could also slap on a bigger, more powerful cell onto the outside of the tin like these nice 4.5 volt cells. (http://www.browndoggadgets.com/products/4-5v-80ma-cis-solar-cell)

I also some AAA battery holders and very cheap AAA batteries (http://www.browndoggadgets.com/products/aaa-nimh-rechargeable-batteries) for sale that have a much higher capacity than the ones you'd find in your average solar light.

Step 2: Salvage the Solar Lights





God bless the $1 Store and it's amazing Chinese junk. I found my local store selling these cheap plastic solar lights, and I ended up buying all of them. Why ask you would I spend $120 at the $1 Store?

Inside each of these lights is one 3.5 volt Solar Cell, one AAA NiMh battery, one LED, one transistor, and one resistor. That is honestly worth more than $1 when making projects. Plus I can always make runway light patterns across my backyard and see if anyone will try and land there.

If you can't find these solar lights, you can find them in bulk on ebay. You can also just use a couple of regular NiMh AAA batteries and any old solar cell 4 volts or above, but it will cost you a little bit more than $3.

Take apart the head of the solar light. Be careful to remove the little circuit board for future use.

Snip the wires going to the solar panel. Depending on your solar light you can either pry it out with a screw driver or push it from behind. I used a nail to push from the underside. The glue they use isn't very strong and the solar cell is quite sturdy.

The only danger is that you break off the little solder point on the solar cell. If you do this just throw it away and take apart another solar light.

After doing this to both lights you'll now have two solar cells and two AAA batteries.

Step 3: Test Your Radio

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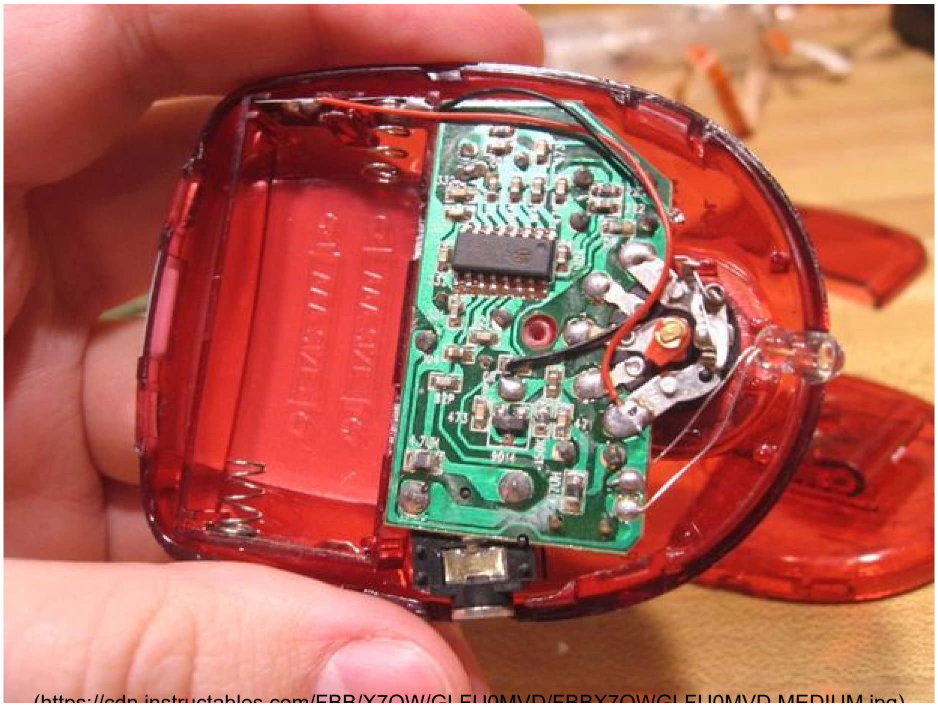
Seriously, test your radio out ahead of time. Better you see if it's working now than after you take it apart.

You can also test out your AAA batteries to see if they're working and if they'll play nice with your radio.

Now you may notice those little white speakers, also from the dollar store. They suck more than the cold vacuum of space. I ended up not using them with this project and instead used them to entertain my cat.

Step 4: Take Apart Your Radio



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This part can be tricky depending on your radio. This is how I took apart mine.

I first unscrewed the back.

After that the only thing holding in the board was the volume nob. If you're lucky the top of your knob will come off (no pun intended). If you look at my board you'll see the "buttons" on my radio are nothing more than some common momentary switches. I even have a little LED there as well. Bonus!

Now the volume nob on my radio would not come off, so I took a different approach. Using some tin snippers I cut apart the plastic case until everything was free. Then I used some little wire clippers and cut the remaining bits away from the knob area. You should wear eye protection during this part as plastic was flying everywhere.

You'll notice that I saved the "Battery Holder" area. Do this as you can. You can just buy a AAA holder for $1, but we're on the cheap here people!

In the end you should have, if nothing else, your radio's circuit board out, and if you're lucky you'll have a battery holder as well.

Step 5: See If It Fits and Works

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My personal favorite case of choice is an old Altoids Tin. No matter what you're using to hold the project in, now is a good time to see if everything fits and that it still works fine.

Mine fit perfectly into the tin case. After hooking up some headphones everything seemed to work fine, including the LED.

This is also a good time to design your internal layout and decide if you have enough room to put the solar cells on the inside or not.

Step 6: To Speaker or Not to Speaker?

(https://cdn.instructables.com/FCZ/CB73/GLFU0MX0/FCZCB73GLFU0MX0.MEDIUM.jpg)

My original plans were to solder in a little toggle switch and some speakers. This way the user could choose between using the internal speakers or extrernal headphones. This didn't work.

For one the little speakers I got from the $1 store sucked, hard. The FM radio didn't have enough power to get much sound out of them, then again neither did my iPod. This would be a really awesome thing to work it in there, maybe by finding some powerful little headphones or one really powerful little speaker. If you can't, I honestly wouldn't worry about it.

(Yes, I tried them out before removing their protective cases. It didn't make a difference. Thats $1 I'll never see again.)

Step 7: Drill Baby Drill

(https://cdn.instructables.com/FG5/KCZV/GLFU0MXB/FG5KCZVGLFU0MXB.MEDIUM.jpg)

So instead of doing internal speakers I just made a hole for the headphone jack.

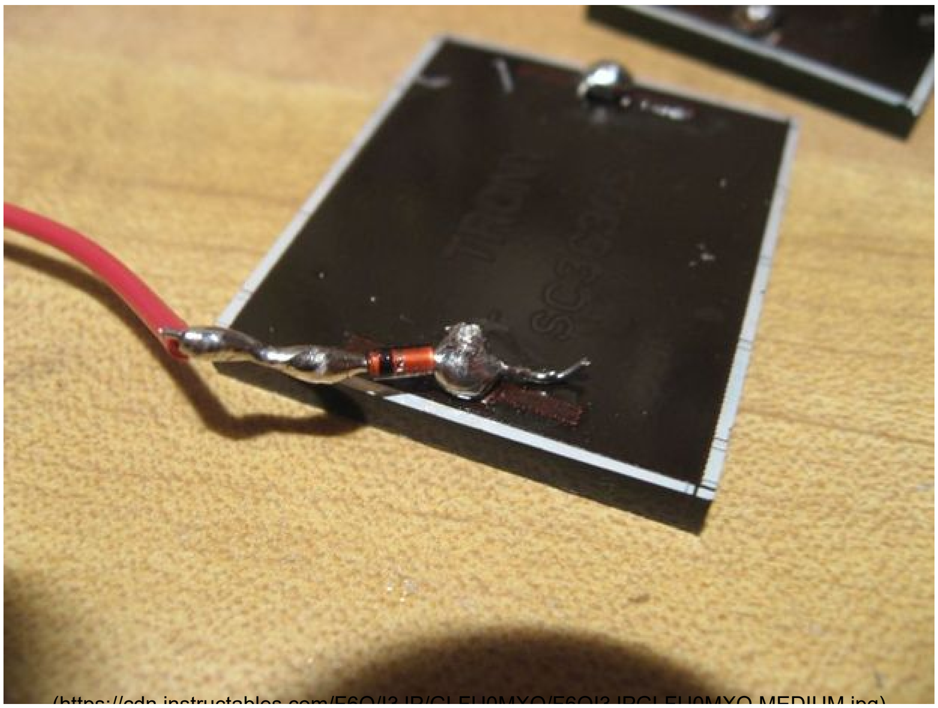
To do this I first lined up everything inside, then marked where I wanted to drill on the outside.

Drilling Altoids tins is easy. Just be careful. Get a good RPM going, press some, and make sure your fingers are safe. You may want to file the inside of your tin if you've got lots of metal bits poking things. (I didn't, but you never know.)

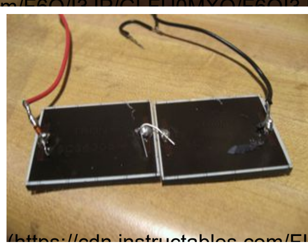
It also doesn't hurt to have a backup tin around. Just in case.

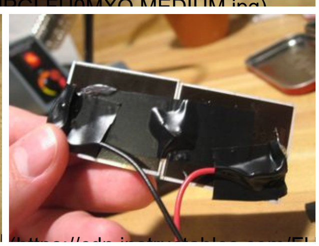
Make sure your headphone jack goes all the way into the drilled hole! If nothing else test that your headphone will in fact work with how you've got it set up!

Step 8: Wire Up the Cells



(https://cdn.instructables.com/F6O/I3JP/CL5U0MXQ/F6OI3JPCL5U0MXQ.MEDIUM.jpg)





If you have a multi-meter test your solar cells out. The ones I used each put out between 3.3 - 3.5 volts.

These cells are great for charging up a single AAA battery of 1.2 volts, but now we're using two AAA batteries in a series for a total of 2.4 volts. Seeing as how the goal of this is to be an emergency radio and be able to charge up even in bad weather we should boost the voltage on our solar cells. (Or you can use any solar cell or group of cells (http://www.browndoggadgets.com/collections/solar-cell)that put out more than 4 volts that you have around.)

To do this we'll be connecting our cells in a series, which means the amps will stay the same but our voltage will double.

First, solder a long wire onto the diode end with the black strip. Then solder the other end of the diode to the positive tab of one of your solar cells.

Solder a long wire onto the negative tab of the *OTHER* solar cell.

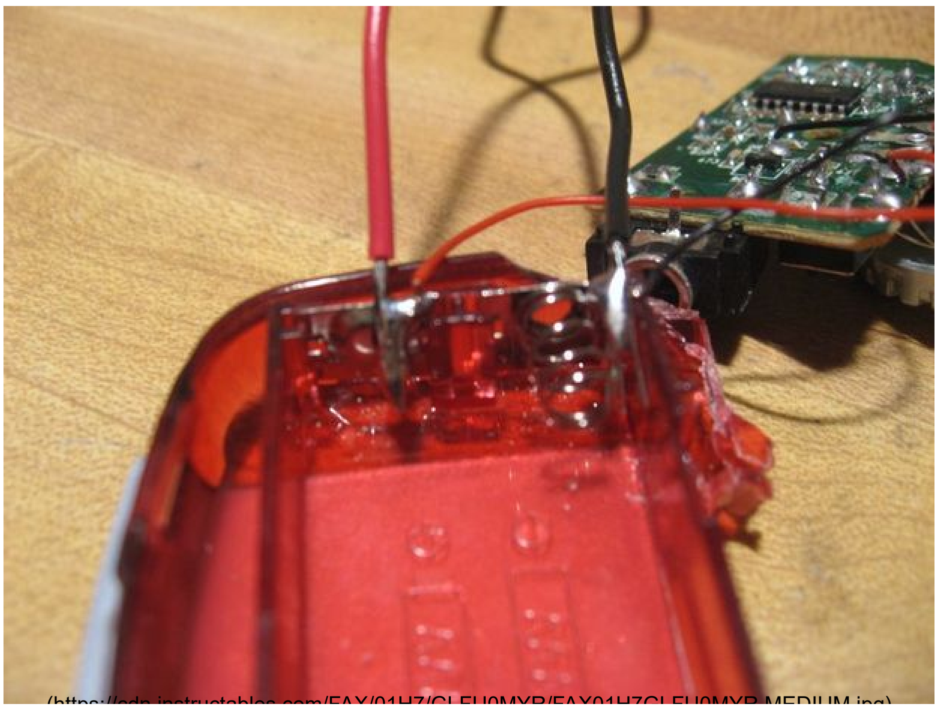
Each cell should have one wire now. One positive (with a diode) and one negative.

Now connect the two cells using the two remaining soldering points, AKA bridge the remaining positive and negative solder points. I just used a bit of scrap wire, anything will do.

When you're finished use some tape to hold down the wires and to protect the solder points.

If you're at all confused just look at the pictures below.

Step 9: Wire Up the Cells and Battery Pack



(https://cdn.instructables.com/FAX/01H7/GLEU0MYB/FAX01H7GLEU0MYB.MEDIUM.jpg)

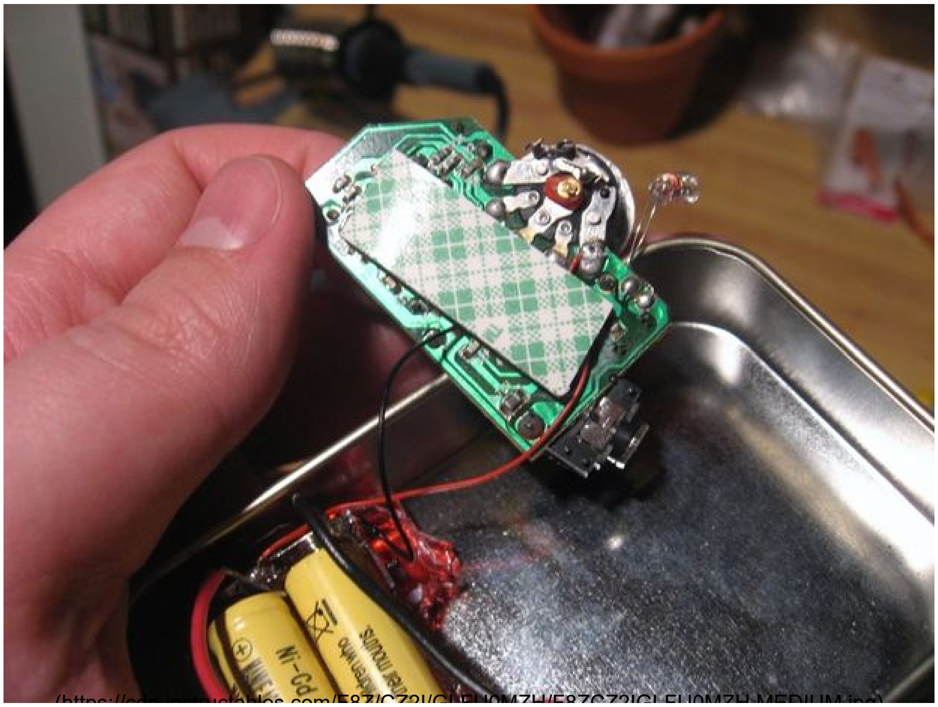
Now wire the positive and negative wires from the cells into your circuit.

You can either wire them directly to the board or to the battery pack. I choose to wire them directly to the battery pack area.

Positive to the positive tab, negative to the negative tab.

Sorry for the blurry photo, I didn't notice that until I starting writing.

Step 10: Tape It Up



(https://cdn.instructables.com/F8Z/CZ2I/GLFU0MZH/F8ZCZ2IGLFU0MZH.MEDIUM.jpg)

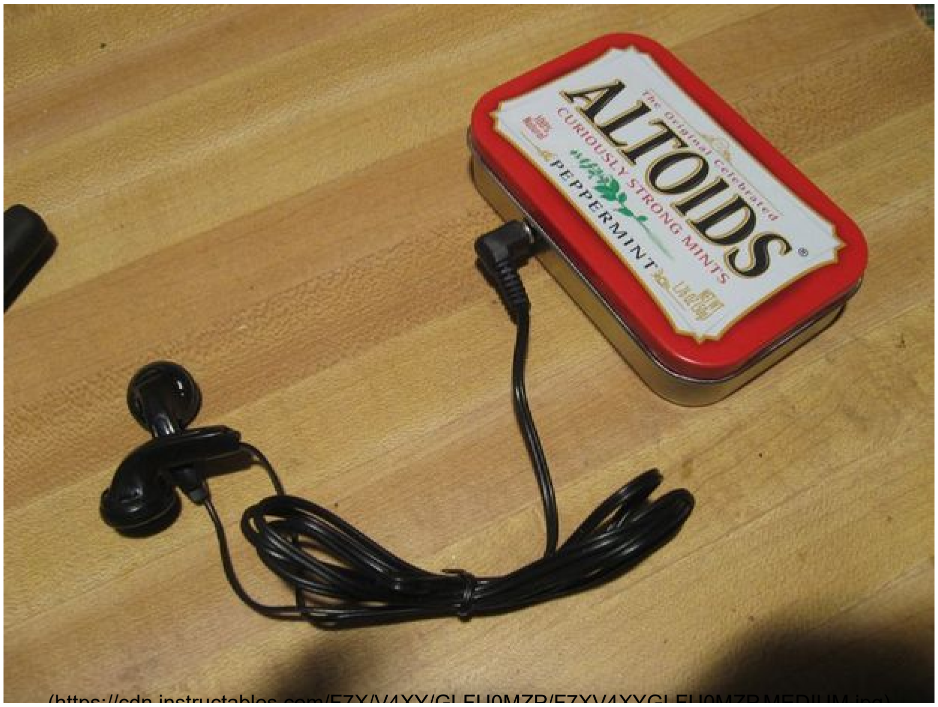
Once again, test it to see if it works. Use a multi-meter to see if power is flowing properly, or just put it in some sunlight and turn the radio on. Depending on how many amps your cells put out the radio should work, though if they're super cheap they might fall flat on directly powering your radio. That's ok, thats why we have batteries.

I used some double sided foam tape to secure everything inside. It keeps the circuit board from touching the metal tin area. If you're worried about shorts just put some electrical tape on the bottom of the tin.

Just be sure to line up your headphone jack and that inserting headphones doesn't unstick your circuit board.

Hot glue also works just fine.

Step 11: Finished!



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(https://cdn.instructables.com/FKKO4FAGLFU0MZQ/FKKO4FAGLFU0MZQ.MEDIUM.jpg)

Everything fits into the Altoids tin and it easily shuts. Now I have a little radio that's solar charged and has a little LED. That wasn't so bad. It even gets a signal through the Altoids tin.

Plus in a pinch you can swap out the AAA batteries for regular ones OR use the solar cells to charge up other dead NiMh AAA Batteries you have.

Other Ideas that would be easy to do if you're willing to put in the time and parts.

1) Use a rechargeable 3V coin cell or ultra capacitor to save space.

2) Put solar cells on the outside, and speakers inside.

3) Work in some retractable headphones or some speakers.

4) Drill a hole for the LED to stick out the front and also have a button on the outside to work the LED. (if your radio has an LED like mine does. Or heck, wire in your own LED into the circuit.)

Support Me By Buying Some Parts...

If you can't find solar cells or cheap AAA batteries, I have quite a few on my website BrownDogGadgets.com (http://www.browndoggadgets.com/). The same solar cells I use to make my Solar Cockroach would work great for this project. You could also slap on a bigger, more powerful cell onto the outside of the tin.

I also have some AAA battery holders (http://www.browndoggadgets.com/collections/battery-holders) and very cheap AAA batteries (http://www.browndoggadgets.com/products/aaa-nimh-rechargeable-batteries) for sale that have a much higher capacity than the ones you'd find in your average solar light.

I also have a wide range fun fun little kits you can put together if you need a little weekend project.

Step 12: Version 2.0

(https://cdn.instructables.com/FVU8U28/GLK0JEXB/FVU8U28GLK0JEXB.MEDIUM.jpg)

So I gave building one of these a second try and it worked out a bit better. This version is just like the old version, except on steroids and a bit more expensive.

I used another $1 Store Radio as well as managed to fit in some $1 headphones. Instead of using the $1 Store solar lights I instead used three 1.5 volt 50 ma solar cells which are smaller and more powerful. I also used some higher capacity AAA batteries I had.

The total cost of this one is about $6-7. Twice as much as the original one, but still much cheaper than buying a store bought solar radio and far more cute in this Altoids Tin.

Oddly I now have a complete solar Altoids kit setup in my room. Solar Radio, Solar Flashlight, Solar USB Charger... In the event of a massive power outage (or zombie invasion) I think I'm set.

Comments

be nice

We have a be nice comment policy.
Please be positive and constructive.

I Made it! Add Images Post Comment

Haysaustin21 (/member/Haysaustin21/) 2016-10-06 Reply

What wire did you use

What kind of FM radio is that (i cant really find one of those online)

What tape did you use

BrownDogGadgets (/member/BrownDogGadgets/) ▸ Haysaustin21 (/member/Haysaustin21/) 2017-10-04 Reply

22 Gage.

$1 Store FM Radio. From Dollar Tree.

Electrical tape. Off the shelf.

lewisgary629 (/member/lewisgary629/) 2017-08-24 Reply

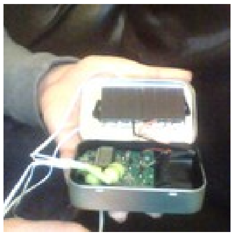
Why tear apart a functioning radio and stick it in a can? Open the radio, attach the wires from the cell(s). Touch of glue, Velcro on radio and on back of cells to back of radio. Close the radio. Turn on.

BrownDogGadgets (/member/BrownDogGadgets/) ▸ lewisgary629 (/member/lewisgary629/) 2017-10-04 Reply

Because it's fun.

christina.liittle (/member/christina.liittle/) made it! 2014-12-06 Reply

Fun!



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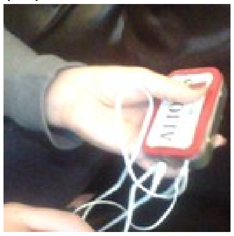


(https://cdn.instructables.com/FS8/JW09/I3BHBPCU/FS8JW09I3BHBPCU.LARGE.jpg)

(https://cdn.instructables.com/FJL/YJ5L/I3BHBPCW/FJLYJ5LI3BHBPCW.LARGE.jpg)

BrownDogGadgets (/member/BrownDogGadgets/) ▸ christina.liittle (/member/christina.liittle/) 2017-09-28 Reply

Ha, very well done!

jerry.ericsson2 (/member/jerry.ericsson2/) ▸ christina.liittle (/member/christina.liittle/) 2016-09-01 Reply

Man I gotta say, this type of project must do wonders for Altoids sales! I never tried an Altoids until I got into project building. Now you can find me sucking on these wonderful little mints day and night, just to get those cans empty so I can do another project. My most recent was an Arduino based oscilloscope that fits the can nicely with a small 84X48 monochrome screen, using a 9V rechargable battery as power supply.

SarahH25 (/member/SarahH25/) ▸ jerry.ericsson2 (/member/jerry.ericsson2/) Reply 2017-07-01

https://www.papermart.com/silver-tall-rectangular-... (https://www.papermart.com/silver-tall-rectangular-hinged-tin-can/id=50895#50895)

Someone posted this link somewhere, I forget...but just in case you get burned out on mints, or lose your sense of taste.

BrownDogGadgets (/member/BrownDogGadgets/) ▸ christina.liittle (/member/christina.liittle/) 2015-03-01 Reply

Super well done!

Korzer (/member/Korzer/) made it!

2016-10-14 Reply

I made one too, but as a case I took a Cigarette Box and glued all the electric parts inside. Also I figured out which circuit is delivering power when I turn on this radio and I soldered an indicator Led to the circuit. It's a pretty nice Radio and has a really good sound. This will take its place in my Camping and BOB bag

(https://cdn.instructables.com/FMG/1YP7/IU9ULDDS/FMG1YP7IU9ULDDS.LARGE.jpg)

(https://cdn.instructables.com/F5M/OC8K/IU9ULDDU/F5MOC8KIU9ULDDU.LARGE.jpg)

(https://cdn.instructables.com/FJQ/YAIM/IU9ULDE7/FJQYAIMIU9ULDE7.LARGE.jpg)

BrownDogGadgets (/member/BrownDogGadgets/) ▸ Korzer (/member/Korzer/)

2017-09-28 Reply

Cool beans!

BrownDogGadgets (/member/BrownDogGadgets/) 2011-06-19 Reply

Just because I'm a teacher doesn't mean that I'm not human.

With feelings to be hurt...

Sniff...

IngenuityAtWork (/member/IngenuityAtWork/) ▸ BrownDogGadgets (/member/BrownDogGadgets/)

2017-09-09 Reply

I like your sense of humor and your (I assume?) dog. Nice instructible too

Orkekum (/member/Orkekum/) ▸ BrownDogGadgets (/member/BrownDogGadgets/)

2012-12-23 Reply

teachers are awesome c:

Orkekum (/member/Orkekum/) 2012-12-23 Reply

awesome idea and well written, i can buy cheap radio with a scan button and a return one

IngenuityAtWork (/member/IngenuityAtWork/) ▸ Orkekum (/member/Orkekum/) 2017-09-09 Reply

Diodes allow electrons to flow in only one direction. In this case I believe it is to keep the battery from discharging back through the solar panels.

PogueMahone1775 (/member/PogueMahone1775/) 2017-09-07 Reply

What was that website again??? LOL

Between survival kits, survival candles, portable stoves, and now radios, I don't know which of my Altoid cans actually has mints in them! This is so cool!

mdempsey617 (/member/mdempsey617/) 2017-02-09 Reply

This is amazing! I want to use the same idea, but with LED lights. What type of safety precautions would I need to do this?

Thanks!

Colaris (/member/Colaris/) 2015-06-15 Reply

If it's powered by the Sun do you need the batteries?

gmorrison2 (/member/gmorrison2/) ▸ Colaris (/member/Colaris/) Reply 2016-09-03

yes, if you want to use it at night, or in a heavy storm, or inside

spark master (/member/spark+master/) 2016-09-01 Reply

As jerry.ericsson2 pointed out AM is what ya need. FM is line of sight. I can key up the Limark repeater system from the top of bear Mountain along the Hudson River on 1 watt from an HT on a crappy rubber duck, but at sea level you gotta be close. If the stinky brown stuff hits the whirley bird thing AM is what what will hear important info, not FM.

A really nice am Xtal radio with a plug in wire antenna might be useful If you can couple it to a small amp, then it can be heard by all, w/o cans, (headphones).

There used to be am radio receiver modules you could buy or you can gut a small am radio. They usually are crap, but if you make an external antenna option or a "kludge",(kludge has many meanings), but I refer to a table top antenna that is a cross on a base with a coil spun around it like a web. One could glue a giant coil of say 22 guage enameled wire on a flap of stiffish canvas and you have a rollable coil antenna. So when you hoist your food supply up into a tree to keep the bears from eating it first, your antenna is up high. Course you can just as easily tie the end of the wire to the bag you hoist up as well.

That said I liked you toy it has merit as a starting point. Unfortunately Lindsay's publications is out of business......he had all the books you could imagine on this stuff. The simple horn speaker attachments you see for smart phones can

be used to amplify a Xtal earpiece so you do not need a set of phone. I think multiple parallel antenna strands would also help.

here is a book I saved from the recycle truck:

https://archive.org/details/principlesunderl00unit...
(https://archive.org/details/principlesunderl00unitrich)

If you got through HS Physics and want to understand how radio works try it from page one to the end. I took radio repair in in HS and I got it, but this is more basic, it predates superheterodyne receivers. Spark Gap Transmitters/receivers.

---

jerry.ericsson2 (/member/jerry.ericsson2/) 2016-09-01 Reply

Cool indeed. I would put one of these together, but here on the great plains of South Dakota, FM radio is only a dream that is realized when we travel to bigger cites where such signals exist. In fact here in the small town on the prairie where I exist, even Ham radio operators such as myself need a very tall antenna to reach any other Ham's even on common talk around bands, such as the 2 meter. The only option would be an AM radio, and as such would not be very useful in an Altoids Can.

---

wazy801 (/member/wazy801/) 2014-01-09 Reply

why do you have to drill on step 7?????

---

jerry.ericsson2 (/member/jerry.ericsson2/) ▸ wazy801 (/member/wazy801/) Reply
2016-09-01

I have dozens of old drills laying around but when it comes to these cans, I never use them. I simply use screwdrivers to punch the holes. I start with a small driver and work my way up to the size I need. The tin is so thin that it is easy and much quicker then drilling.

Bhares Lawke (/member/Bhares+Lawke/) ▸ wazy801 (/member/wazy801/) Reply
2014-06-26

To make a hole for an earphone jack

A boy from China (/member/A++boy++from++China/) ▸ Bhares Lawke (/member/Bhares+Lawke/) 2014-08-20 Reply

Oh,my radio is the same as yours.

PurpleN3on Jr (/member/PurpleN3on+Jr/) 2015-10-20 Reply

Rage quit

PurpleN3on Jr (/member/PurpleN3on+Jr/) 2015-10-19 Reply

Frustration

Femetheus (/member/Femetheus/) 2015-08-14 Reply

I used the same radio, but the wires connecting to the battery came off the plastic case as I was removing the housing, and now I can't get them back on. How are these little wires affixed originally when the radio comes from the store, with glue? Or am I just better off buying another little radio to start again?

T0BY (/member/T0BY/) 2015-06-18 Reply

This is a beautifully elegant little radio. You have done very well to make it for so little money, I am very impressed!

CaptainLlamas (/member/CaptainLlamas/) 2015-05-24 Reply

Where did you get that one type of radio? I looked everywhere, and the only place I found it was Alibaba, but it was only in 5000 piece bulk package. I am in North Carolina, if there are any specific stores that have it here.

MatamoriJon (/member/MatamoriJon/) 2015-04-25 Reply

Hey nice instructable, i have a few questions though.

First, can i use a solar cell from a calculator?

Second, does it have to be a specific diode?

Third, can i use normal batteries instead of those used for solar cells?

Fourth, whats the diode for?

BrownDogGadgets (/member/BrownDogGadgets/) ▸ MatamoriJon (/member/MatamoriJon/) 2015-05-11 Reply

1) No, not strong enough by a mile.

2) 1N914 is the standard and super common one to use.

3) No, you need rechargeables so they can recharge. Regular batteries will... possibly leak or explode.

ThisIsMyNameOK (/member/ThisIsMyNameOK/) 2015-02-26 Reply

I could (almost) make one of these following these instructions. I even have everything I need already. I was going to say except for the diode, but odds are there are some floating around here somewhere...

Just one question: Why do you have to throw the solar cell away if you break off the solder point? Can't you just re-solder it? I know this was already asked, but I don't see an answer, and I was wondering the same thing.

BrownDogGadgets (/member/BrownDogGadgets/) ▸ ThisIsMyNameOK (/member/ThisIsMyNameOK/) 2015-03-01 Reply

With these type of cells if you break off the solder point, then there is no way to make a connection. If you use better solar cells you'll have an easier time. I was just using super cheap recycled $1 Store solar cells. Spending $5 on a better solar cell will make life a lot better.

ThisIsMyNameOK (/member/ThisIsMyNameOK/) ▸ BrownDogGadgets (/member/BrownDogGadgets/) 2015-03-07 Reply

Ah... I see. Thank you for your reply. I know nothing about these kinds of things and it just seemed like it was wasteful to throw it away.

klmyles (/member/klmyles/) 2015-02-04 Reply

Would a Digitally Tuned radio work??

(see this one I found - http://www.dollargeneral.com/product/index.jsp?pro...

BrownDogGadgets (/member/BrownDogGadgets/) ▸ klmyles (/member/klmyles/) 2015-03-01 Reply

Probably.

Skeleton key97 (/member/Skeleton+key97/) made it! 2014-04-24 Reply

i made it!!!!!! hahaa. its easy enough

(https://cdn.instructables.com/FY6/TJMA/HUDMWBLZ/FY6TJMAHUDMWBLZ.LARGE.jpg)

BrownDogGadgets (/member/BrownDogGadgets/) ▸ Skeleton key97 (/member/Skeleton+key97/) 2015-03-01 Reply

Nice,

ishiyakazuo (/member/ishiyakazuo/) 2014-07-14 Reply

Just FYI, the reason that this works and receives a signal through the Altoids tin is because the headphones are the antenna. If you use speakers, you might need a separate FM antenna. Hope this helps.

kfrancis91 (/member/kfrancis91/) 2014-06-21 Reply

If you break off the solder point from the solar cell, couldn't you just solder it back on?

josuchav (/member/josuchav/) 2014-04-11 Reply

you misspelt goggles

ajensen27 (/member/ajensen27/) 2014-04-03 Reply

found 2 separate lights around the house. one has a 2/3 aa battery and its panel puts out 1.2v and the other has a AA battery and its panel puts out .95-.97 volts sitting under 40w bulb(it was night out). which panel do i use and how many. also do i need the diode?

Kirbsome! (/member/Kirbsome%21/) 2011-04-23 Reply

Quick tip:
When buying solar powered lights for this, look for blue solar panels. They are usually higher quality than the dark brown ones.

ajensen27 (/member/ajensen27/) ▸ Kirbsome! (/member/Kirbsome%21/) Reply 2014-04-03

thanks good to know

BrownDogGadgets (/member/BrownDogGadgets/) ▸ Kirbsome! (/member/Kirbsome%21/) 2011-04-23 Reply

Very true. Those CIS are dark brown and very high quality...

Theguywithnoface (/member/Theguywithnoface/) 2014-01-16 Reply

This has got to be one of the single most coolest things on instructables!

---

wazy801 (/member/wazy801/) 2014-01-09 Reply

what kind of tap do I use o step 8???

Nhoj16 (/member/Nhoj16/) 2013-08-27 Reply

I just began making this when I realized I'm out of diodes. Will it still function without one?

More Comments

$3 Emergency Solar Radio by BrownDogGadgets (/member/BrownDogGadgets/) in gadgets (/technology/gadgets/)

Download | (/id/3-Emergency-Solar-Radio/) 12 Steps | Collection | I Made it! | Favorite | Share

RF Homebrew Instrument >

Couter: EP frequncy counter

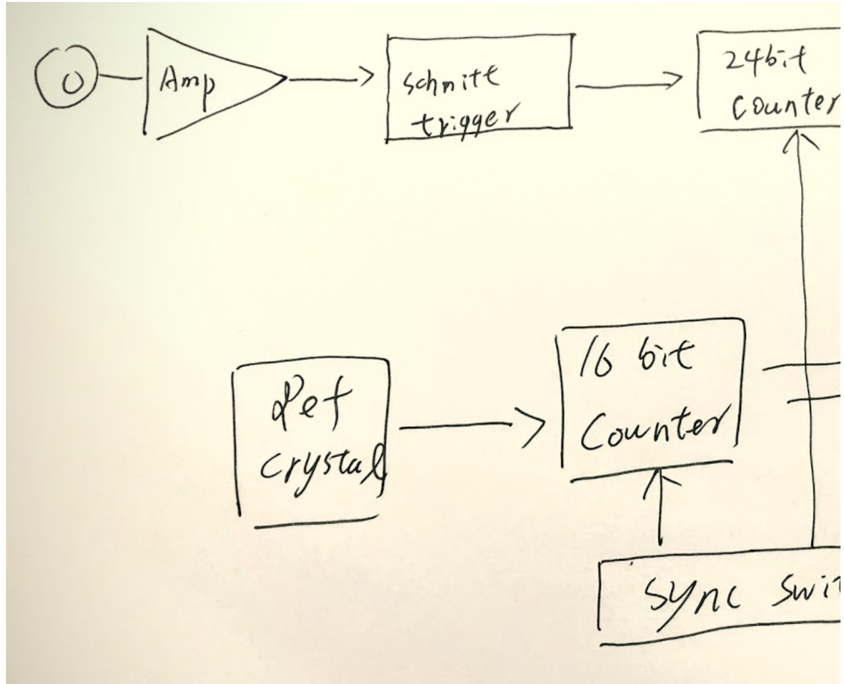
@7/30 2012,

This is the most **decent, High Performance device** i ever design till now. the project completed about 1 years ago, around July, 2011, after a year using, it's time to say, it's my successful first step toward to RF world.

* 12.288Mhz TCXO reference clock. highest reference clock: 50Mhz
* 1Hz resolution up to 120Mhz, without pre scaler.
* **Equal precision design**, avoid +-1Hz, sustaining same precision all the way.
* base on AVR mega8 chip
* High speed digital process chip for all counter parts. TI 74HC series, work frequncy up to 120Mhz.
* 28bit hardware counter. reference clock 24bit hard ware counter.
* built with SMT, PCB size 10cmx6cm
* equip with high resolution L/C meter accessory.
* Module design,separated pre-amplifier board.

The frequency counter is the most easy thing to built for me, and would be the lab grade instrument. it's so useful.

How the Frequency meter works



The counter board

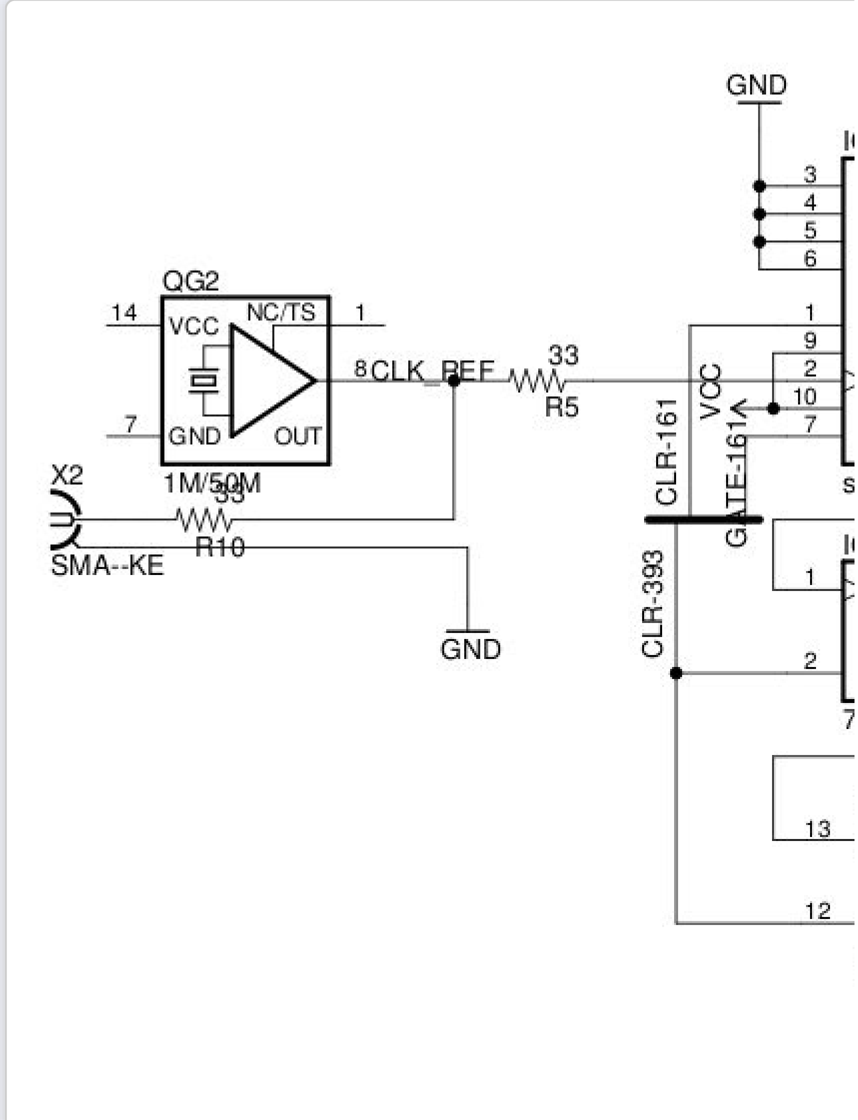
counter board is the core of whole project. basic idea is 2 identical counter for reference clock and the DUT clock. And time gate is control by DUT signal's raise/down edge. so
DUT frequncy= (dut counter)/(reference counter) x reference clock frequncy
using a 12Mhz reference clock ensure 1-10Mhz DUT system error < 1HZ. in practical using, 1-10Mhz crystal oscillate had no +-1HZ jump in short time.

Reference clock counter

Contact me

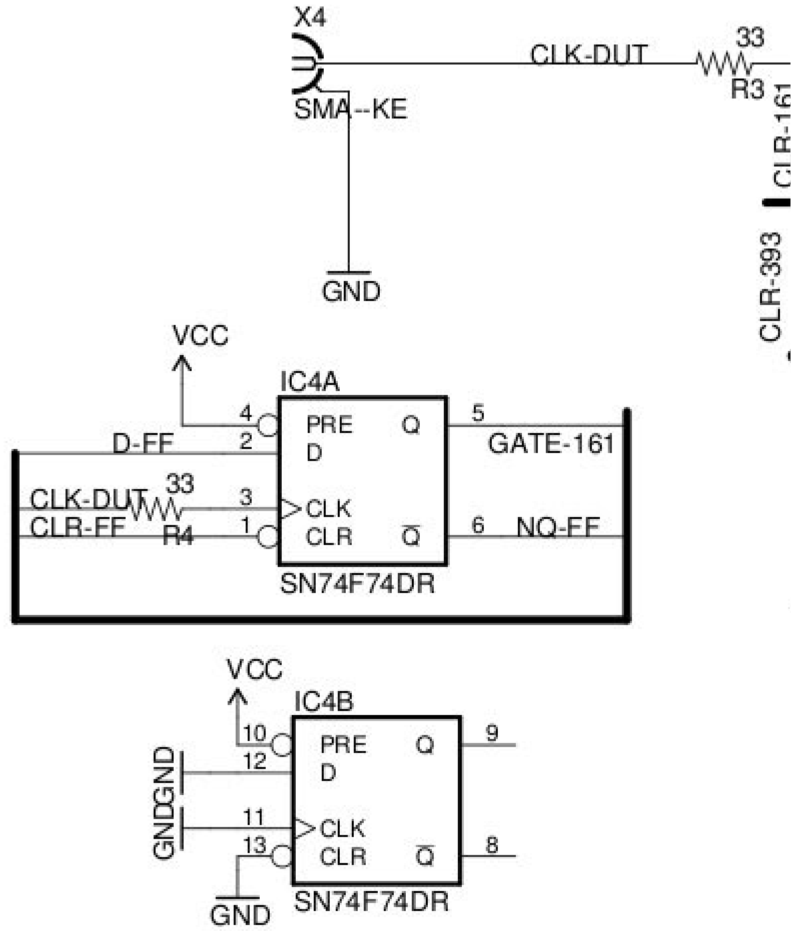
heyongli@gmail.com

G+



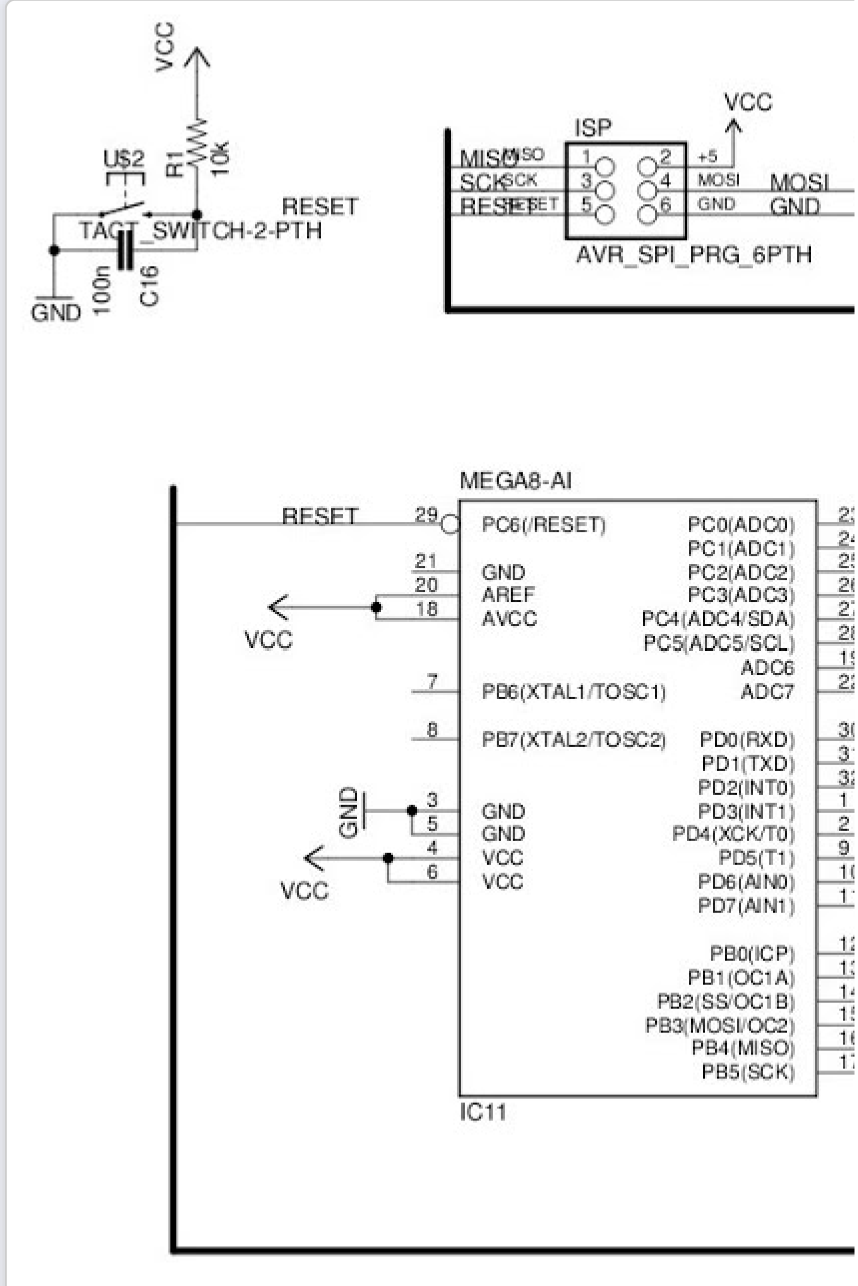
IC5,IC1A,IC1B form a high speed percale but keep the cycle number,this it to say, no **precision loss**.

DUT frequncy counter



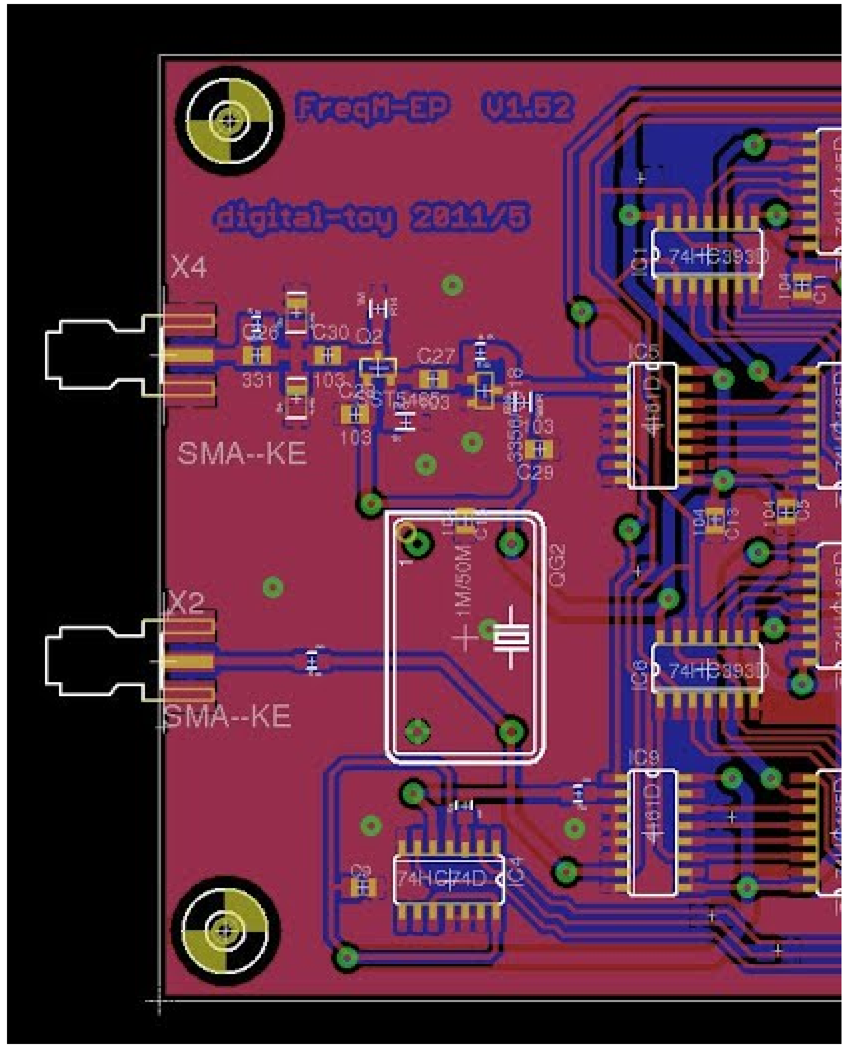
identical to reference counter, but the 74F74 IC4A, control the gate of sample period. to ensure start/stop at DUT's edge pulse.

Control board



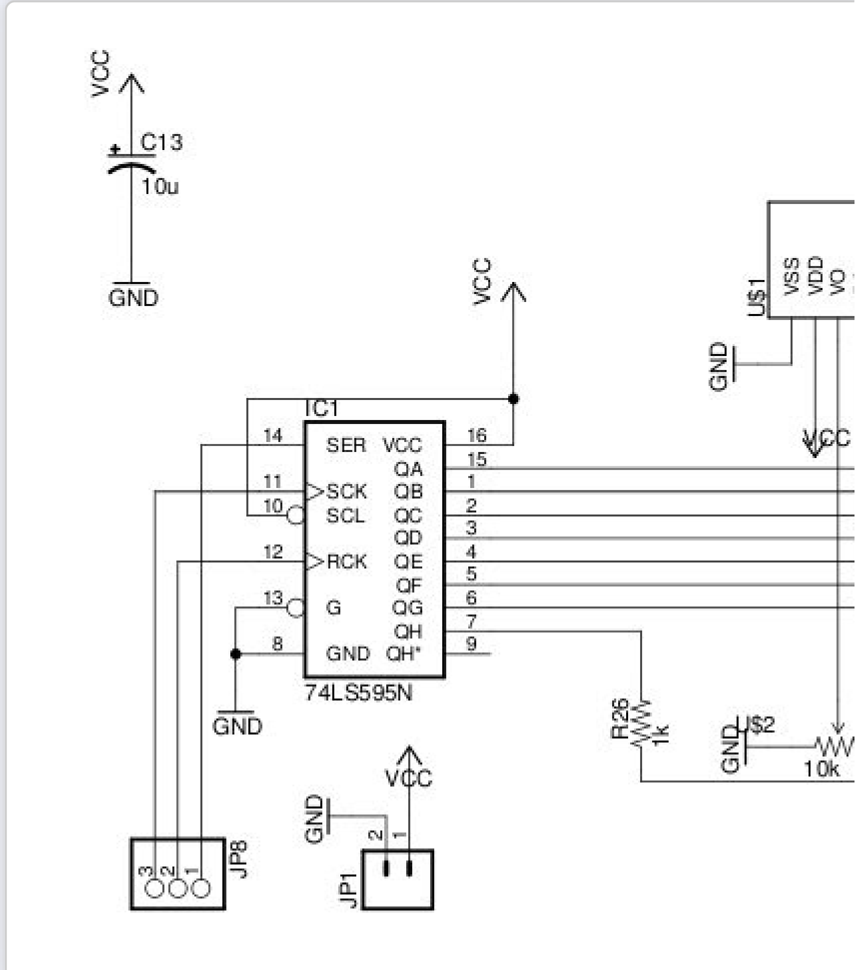
mega8 had a 16bit counter and a 12bit counter, cascade with hardware pre-counter form a 28bit counter for DUT and a 24bit counter for reference clock.

The double side EP counter Main Board.

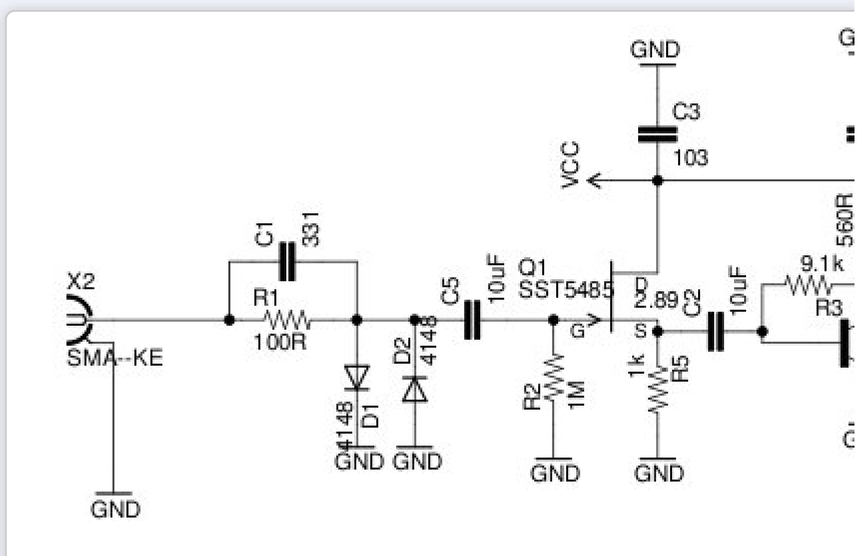


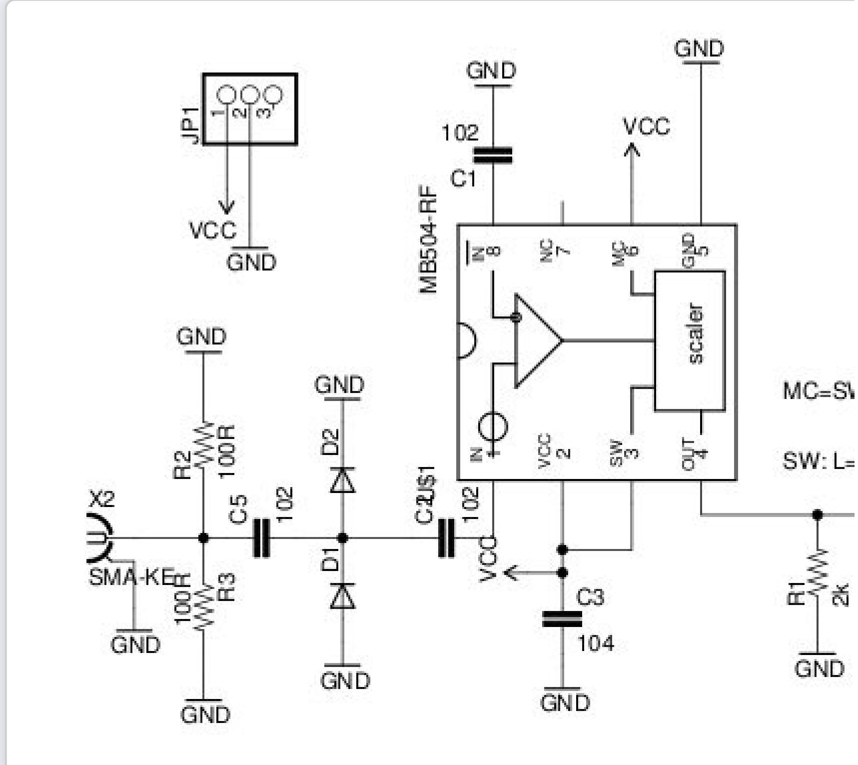
The 3 wire LCD board

utilize the 595 chip, form a SPI bus LCD driver.



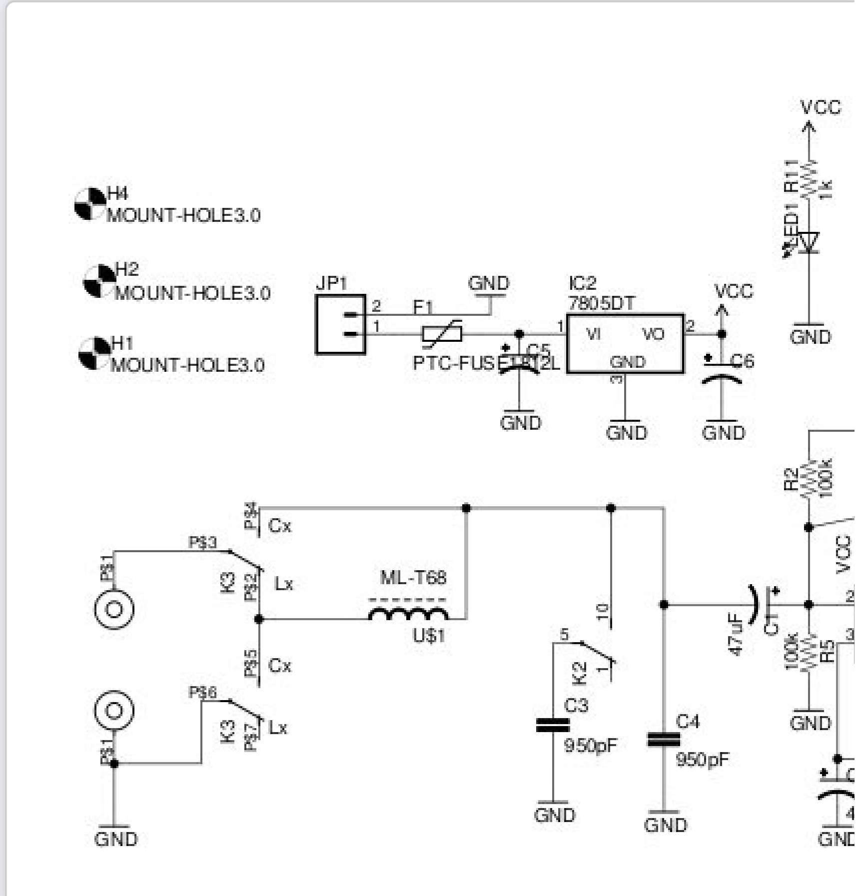
Amplifier and Pre-scaler board





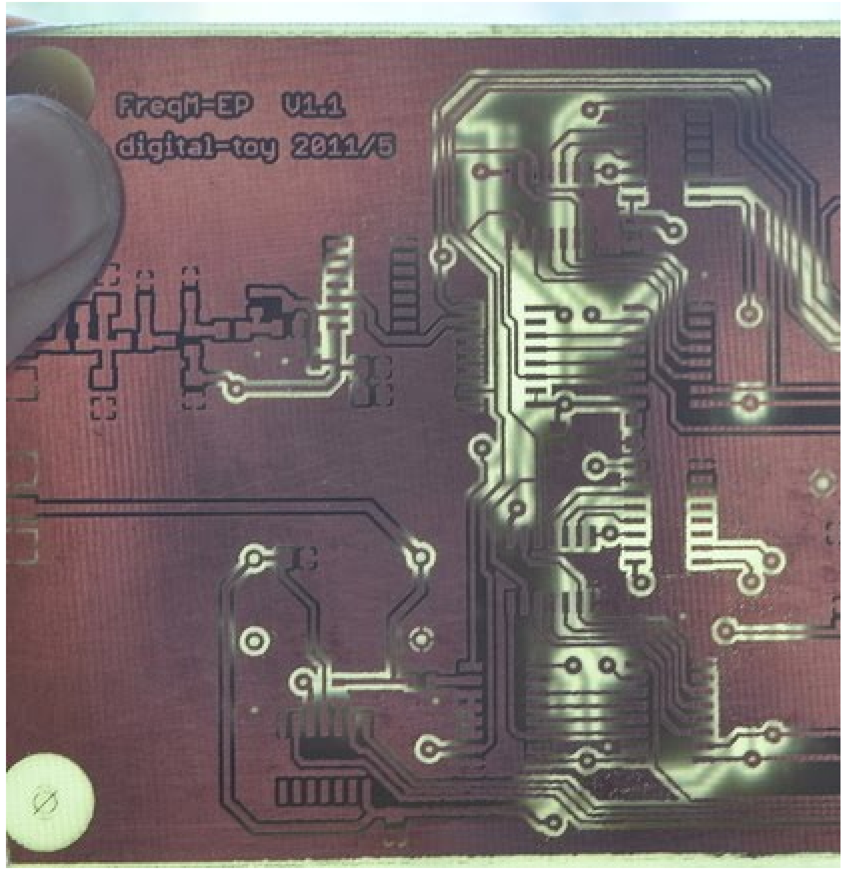
LC meter

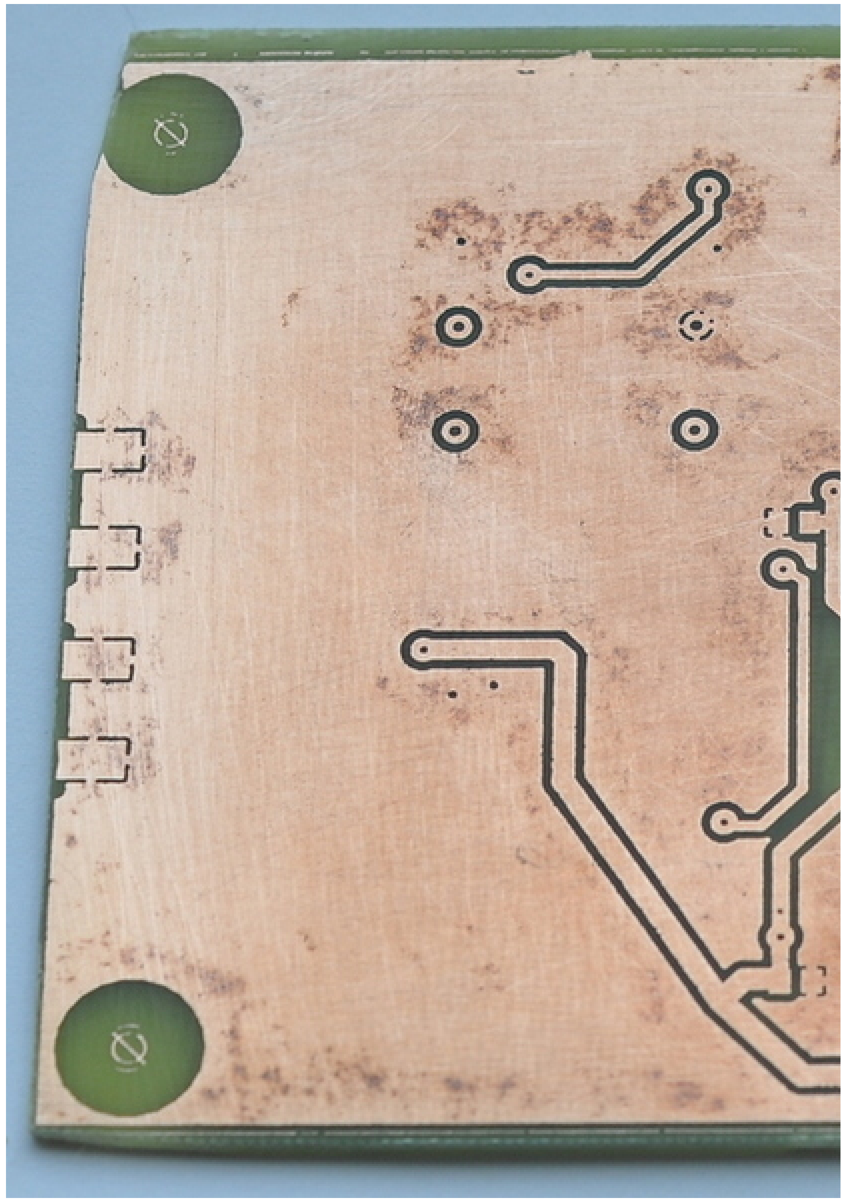
this the clone of famous LM311 LC meter. reference: http://my.integritynet.com.au/purdic/lc-meter-project.htm



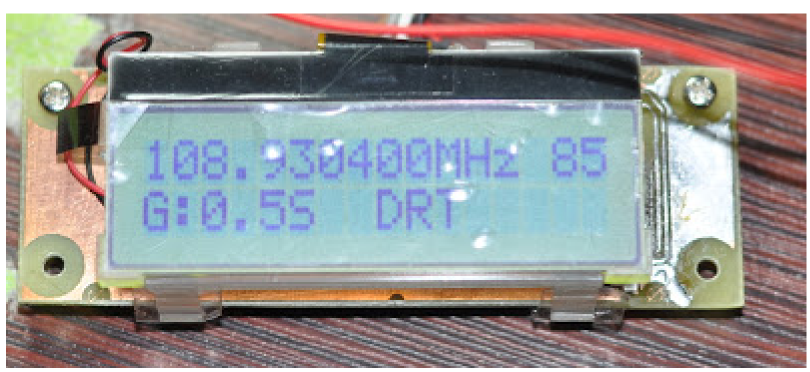
Home brew PCB: perfect hole alignment

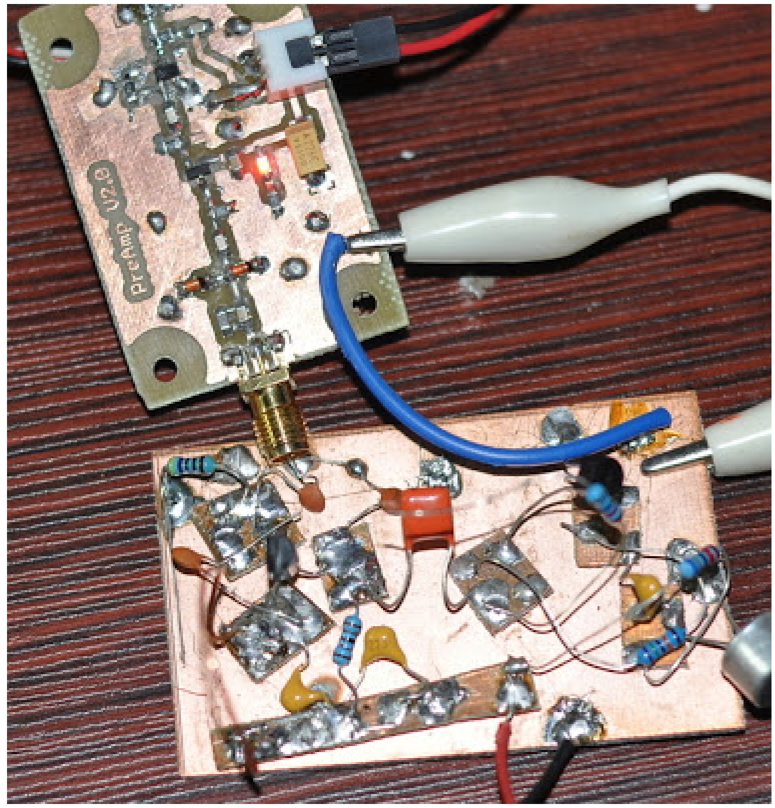
Look, how perfect double side PCB hole is alignment!! even better than some factory grade. This is the secondary board i made for this meter.


FreqM-EP V1.1
digital-toy 2011/5

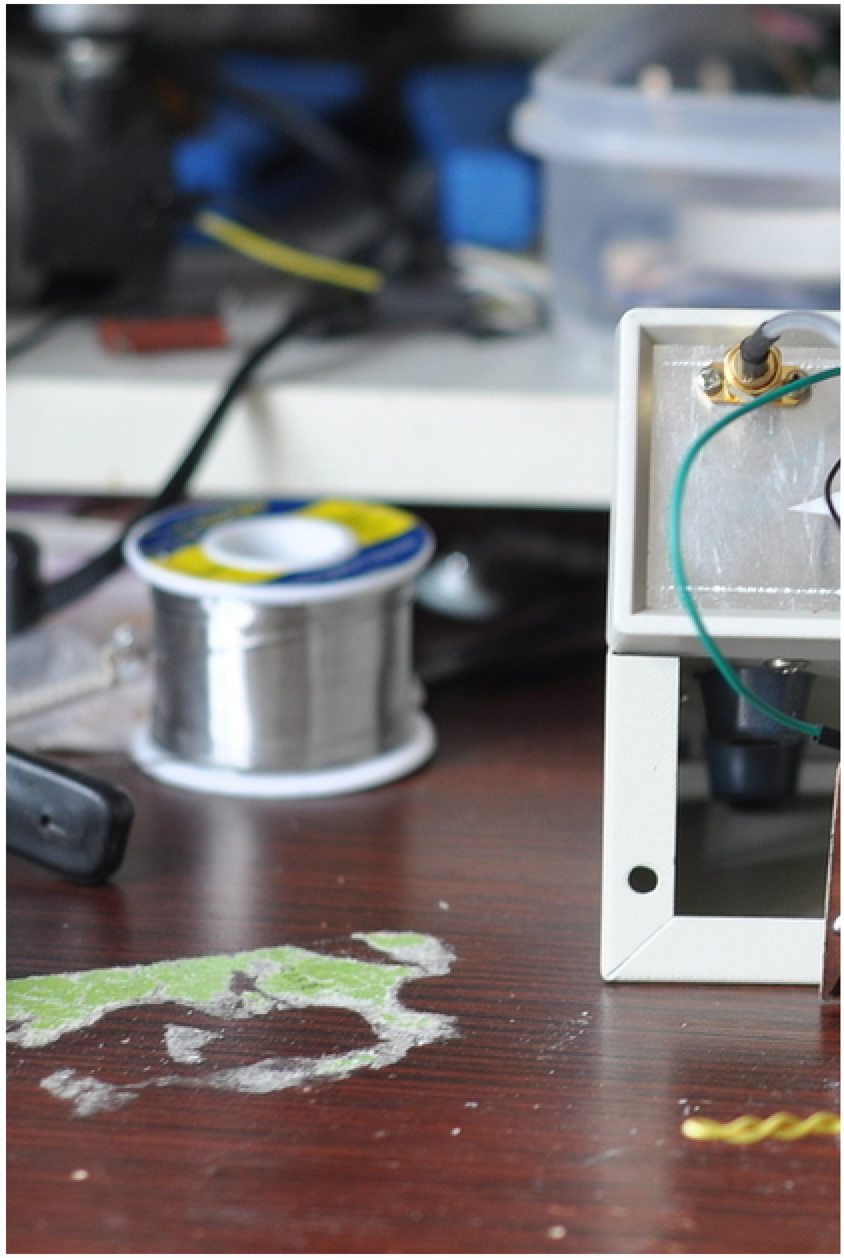


Initial Testing





Boxing Stage 1

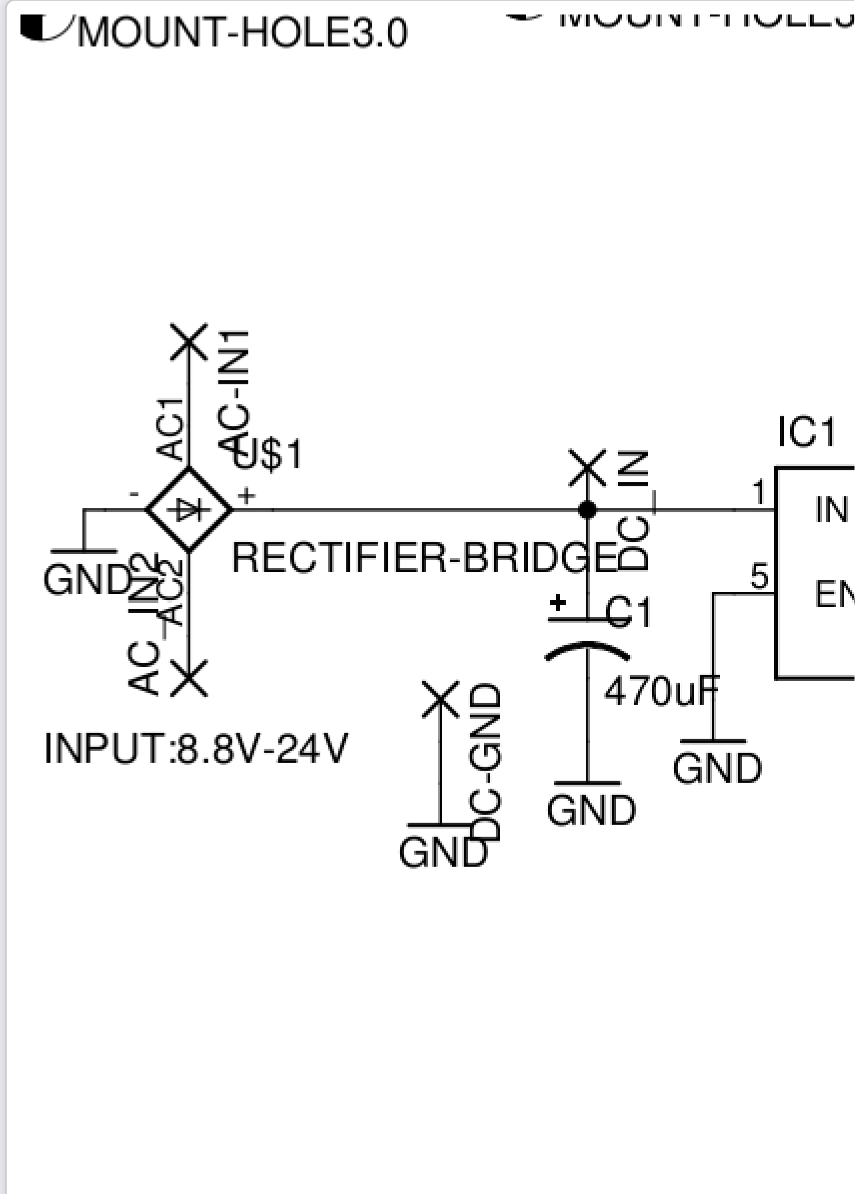


Boxing stage 2

LM2576 Power Board

@April/25 2016

the old instrument box have a power transformer provide 18V output, this LM2576 DC-DC convert it to 7V output, high efficiency and 500mA auto recover fuse protection.



Comments

You do not have permission to add comments.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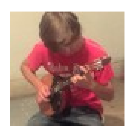

DiggingFox (/member/DiggingFox/)
Follow 16
(/member/DiggingFox/)
Bio: I love simplicity, function and precision job!

More by DiggingFox:


(/id/Wooden-Picture-Frame/)


(/id/Hi-Fi-crystal-AM-radio-tuner-No-565-Miller/)

Hello everyone!

I am big fan of old radios, and I am fascinating how precision were the radios making. 4 months ago, I was just looking for some interesting schematcs, and I found one! It's about 50 years old, but works perfectly, without any power supply. With the reciever you can listen to your favourite radio on middle waves. You just need some electronic components, long antenna, good ground and HI-Z earphones (or amplifier). To make it you don't need any money! All components I used were recycled! Please, respect the nature!!

Let's make it! :))

Hi-Fi Crystal AM Radio Tuner / No. 565 Miller

by DiggingFox (/member/DiggingFox/) in audio (/technology/audio/)

Step 1: Components

ASSEMBLY AND WIRING INSTRUCTIONS FOR THE Miller

NO. 565 MILLER HIGH FIDELITY GERMANIUM DIODE BROADCAST BAND TUNER KIT

You are now the proud owner of a No. 565 Miller High Fidelity Germanium Diode Broadcast Band Tuner Kit . . . the only tuner kit of its kind.

The Miller No. 565 Tuner Kit is the result of masterful engineering and careful planning. Previously sold only as a factory assembled unit the tuner has received overwhelming acceptance by the most critical audiophiles. When assembled in accordance with the following instructions, the No. 565 Tuner Kit will give you a lifetime of trouble-free performance.

Assembly and wiring of your tuner is not difficult. Every possible precaution has been taken to assist you in completing it. Please take the necessary time to assemble and wire the No. 565 Tuner Kit carefully. Read this entire instruction folder before you start the actual assembly. Check each part against the parts list (back page). This way you will become familiar with each part. Refer to the "exploded view" and the photographs to identify the parts and their location.

The Miller No. 565 Tuner is designed to be used with a high gain amplifier or pre-amplifier. It should be connected to the phono or mike jack for best performance. The most satisfactory antenna we have found is a simple long wire approximately 75 feet in length. The antenna should be L shaped, with the vertical portion rising from the tuner to the top of your house and the horizontal portion preferably stretched in a straight line across the roof or to some other support. The wire may be insulated or bare, whichever is on hand. In general, the longer and higher the antenna the better the reception. If space does not permit the use of a long antenna a shorter one may be used and will generally operate quite satisfactorily. No attempt should be made to use the A.C. line as the antenna. This may result in serious damage to the tuner.

To enable the use of earphones with the No. 565 tuner the Miller phono adaptor No. 2705 is available. When earphones are used a good ground connection is also necessary. The tuner may be grounded by connecting the Fahnestock clip on the back of the tuning condenser to a water pipe or equivalent. Soldering methods are very important. Rosin core solder is especially recommended for wiring the Miller No. 565 High Fidelity Tuner Kit.

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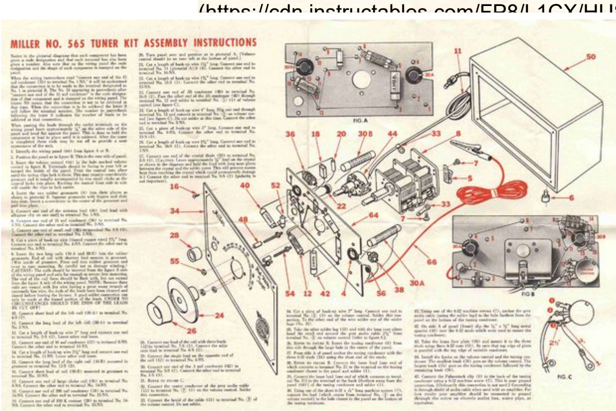

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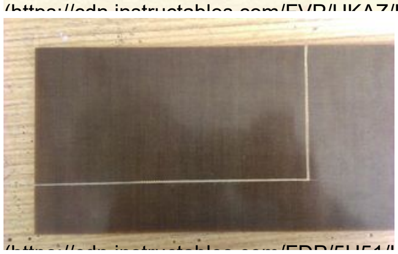

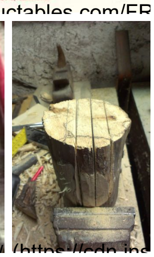

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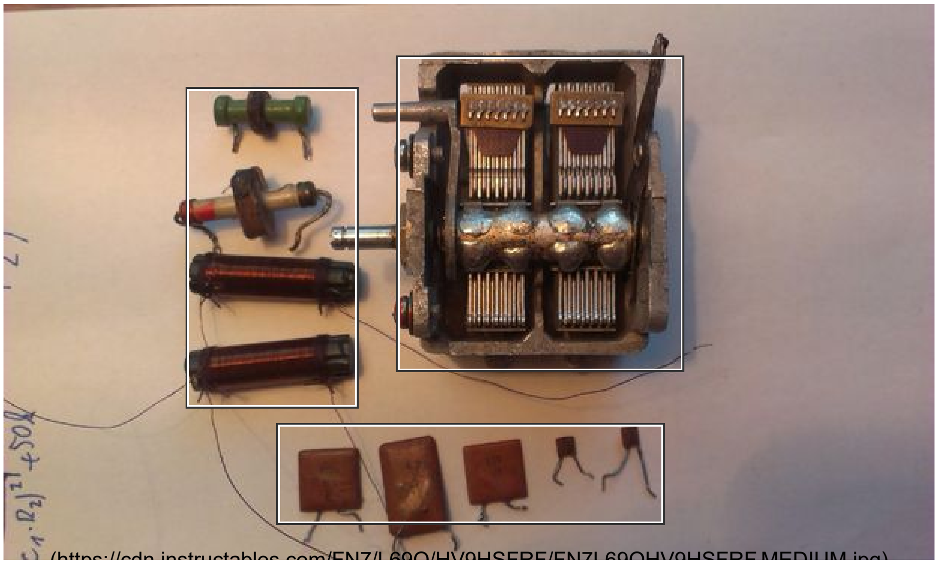

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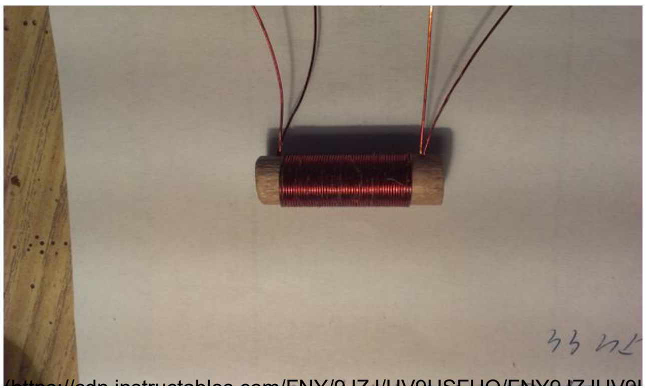

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What you need:

- Epoxy board, or any non-conducting board (for motherboard)
- Metal board (for frontboard, I chose dural)
- Old ugly log (for case)

Electronic parts:

Resistors:

- R1 - 100 kOhms
- R2 - 1 MOhms potentiometer

Capacitators:

- C1 - Tuning capacitator 2 * 500 pF (from an old AM radio)
- C2 - 100 nF
- C3 - 200 pF
- C4 - 50 nF
- Cc1 - 15 pF
- Cc2 - 10 pF

Coils:

- L1 - 250 uH
- L2&L4 - 330 uH (100 turns with 0,21 mm wire on 7 mm in diameter and 29 mm lenght ferrite stick)
- L3 - 20 - 30 double turns on 8 mm in diameter 40 mm lenght wooden dowel, then solder left end of A turning and right end of B turning together
- L5 - 2,5 mH

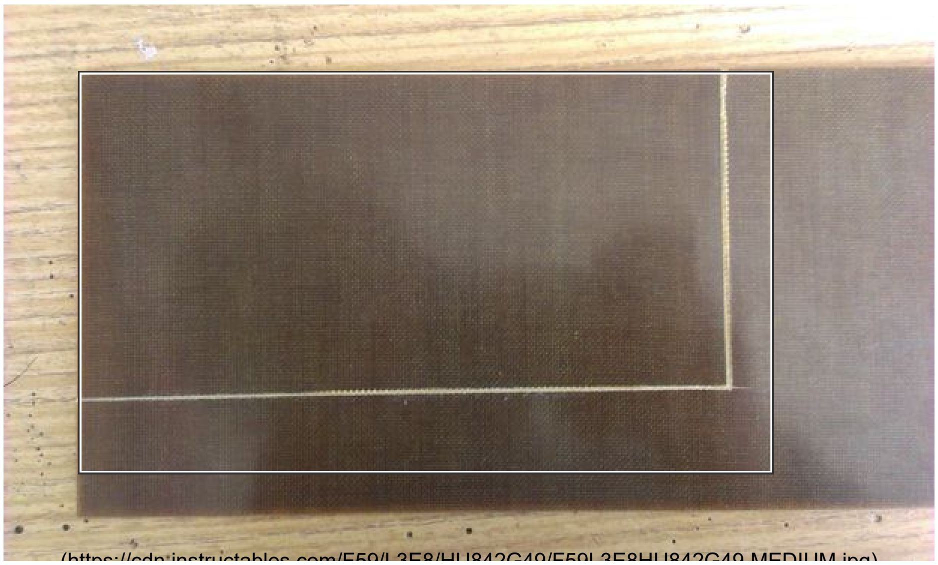
One germanium diode

Note: Be precision while you are winding the coils. After winding is good to measure the inductive of coils. The inductive has to be the same. It is important for future quality receive.

Other:

- Some wires
- Some banana jacks (for antenna, groung, earphones..)
- Long (best 20 meters) antenna
- Good ground (metal heating is fine)
- High Z earphones (best about 1-2 kOhm or more)
- A lot of chocolate (for patience :))

Step 2: Motherboard



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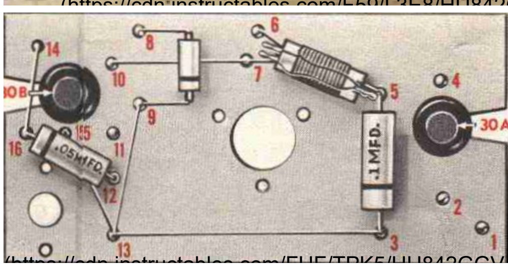
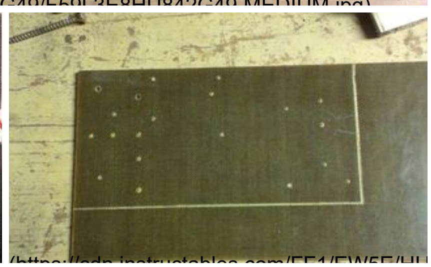
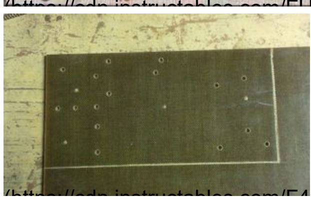
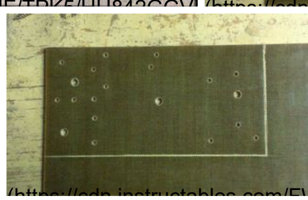
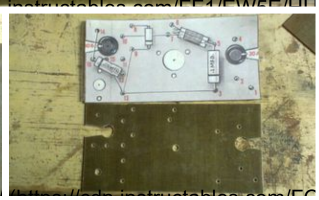








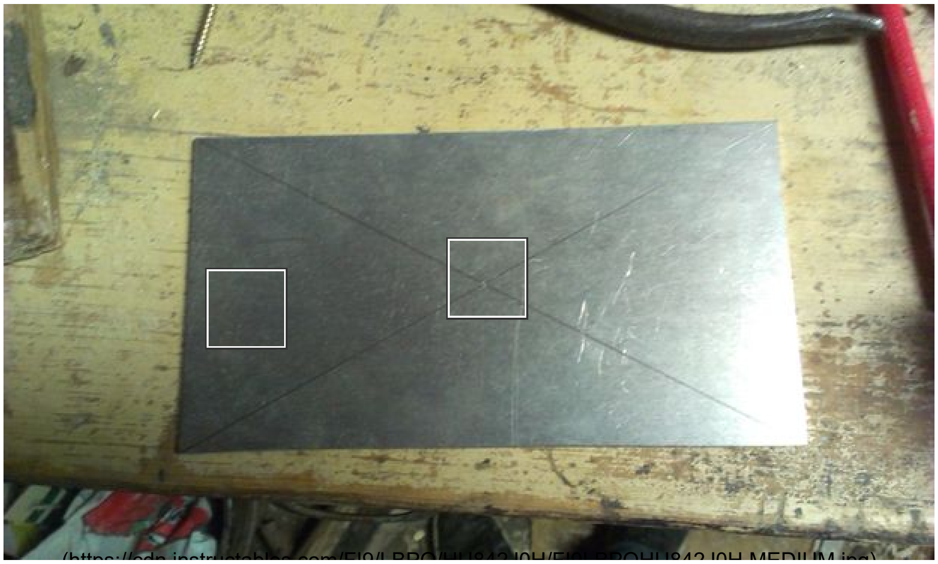


Show All 11 Items

To make a motherboard for the reciever you need comprextit board (or any thin non-conducting board, wooden, platic...). Dimensions of the motherboard are 144 mm * 72 mm.

1. Line the cuprextit board.
2. Print the layout from original manual on paper.
3. Stick the printed layout on the coprextit board.
4. Mark the soldering holes with center punch.
5. Drill all holes you need,
6. Make holder for the ferrite core coils (L2, L4).
7. Rivet the soldering holes with hollow brass (or any solderable metal) rivets.
8. Make BIG hole for the tuning cap!
9. Be happy of the result, you made the motherboard!! :))

Step 3: Frontboard



To make the frontboard I choosed dural board. It is not necessary, I just had what I had.

1. Frontboard dimensions are 170 mm * 90 mm.
2. Cut it!
3. Mark it in the center and drill hole.
4. Making some interesting things for good working cap (ellipse, holes..).
5. Make hole for potentiometer (by your motherboard).
6. More holes for future case.
7. By the Motherboard make into Frontboard 4 holes for some screws
8. Be proud od yourself! :))

Step 4: The Case

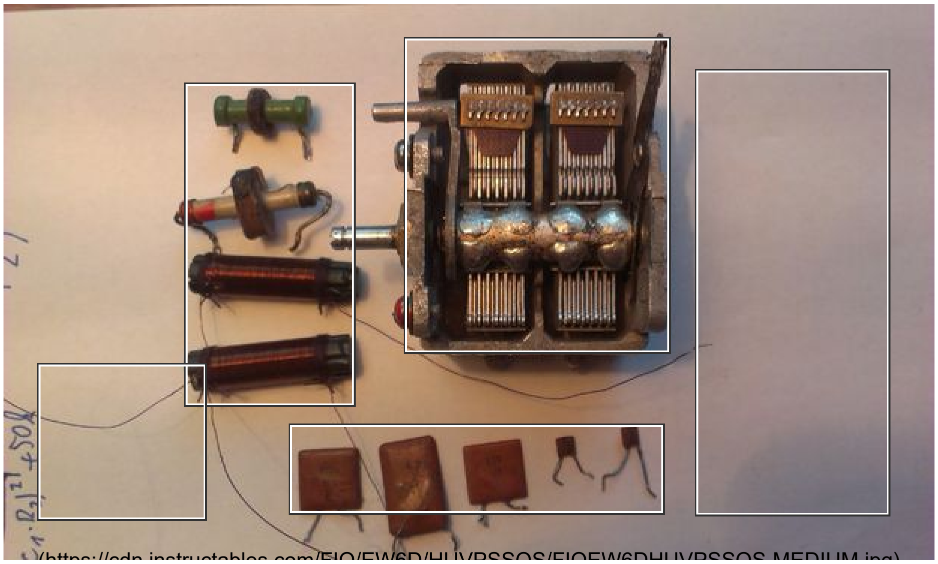
Show All 35 Items

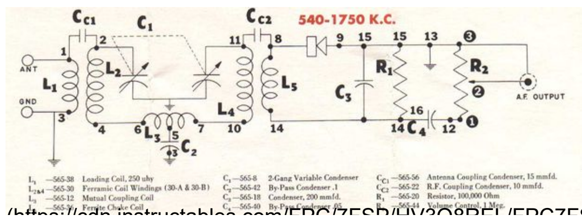
The original case is made from bakelite. I can't make it, so I decided to make it from the best material on the world, from the wood!

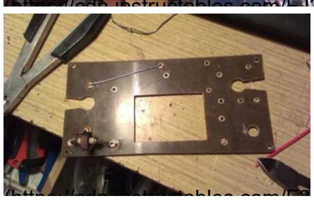
1. Find log (I found old, ugly log, to prove, that the ugly, old log with mushrooms init doesn't worth nothing, I didn't wanna to kill tree :((..please, respect the nature:)) BTW. I thing the tree is **Populus alba**.
2. Saw this log on right lenght. Side boards are 104 * 78 * 14 (lenght * width * thickness) in mm. Bottom and upper boards are 174 * 78 * 14 mm (first piece of log is shorter (104 mm), second one is longer (174mm)). (P.S. Be sure, this is aesthetics matters)
3. Saw it on Boards. Line the log with right dimensions from the middle of log. Once you have it, next step is comming!
4. Cut it on the one side, then in the middle, and on the end on the other side. Now you have 2 wooden boards. Repeat it with the second log.
5. Smooth it to soft and clean surface. (don't do it with sandpaper, it's not nice. I did it with drawknife (or jack-plane), and result was perfect)
6. Cut it on the right dimensions (lenght, width).
7. Sketch and saw dovetail joints (25 and 12,5 mm). Be precise, I choosed 2 dovetail joints on one side.
8. Assembly the BOX!
9. Time to puttying. The putty consist saw dust and glue for wood or paper (everybody knows that white liquid). The putty is for the holes in the case. After puttying, let it dray about 4-7 days, for sure, than sand it with sandpaper, but carefully. :)

10. So, we've got a case. Let's lacquer. I choosed "Boad lacquer", it has nice a bit orange color, for this old, ugly, white wood is good. Inside took only one layer. Outside took 4-6 layer of lacquer.
11. Let it dry, and be happy! :))

Step 5: Electronic Part





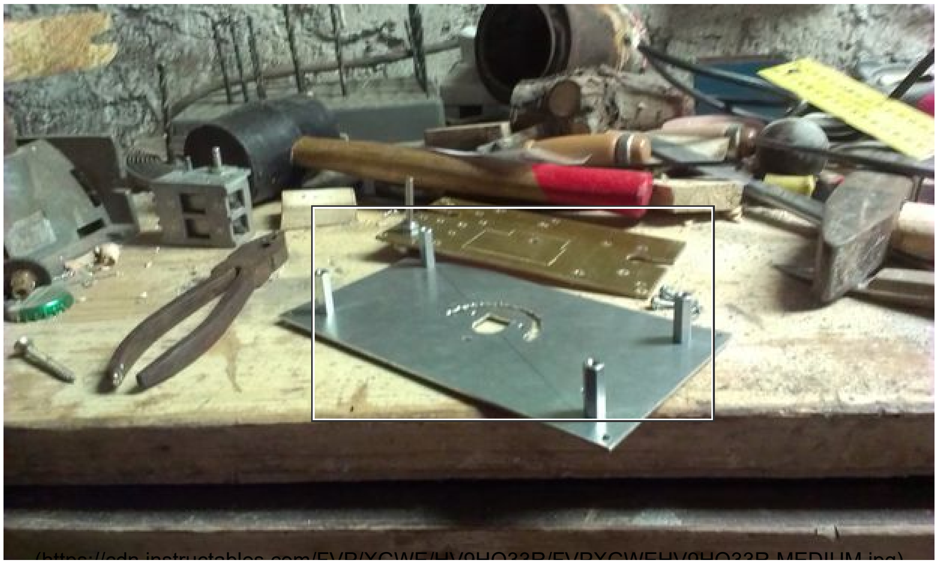


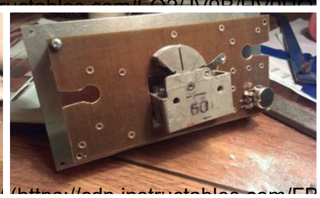
Show All 12 Items

Once you've got motherboard, frontboard and case for radio done, it's time on electronic part!

1. First, collect your electronic parts from step 1
2. Build your alfa version of crystal tuner (this step is not important, you can skip it!)
3. From original instruction lists you can find where every component has be placed. By numbers on schematics (this numbers are also on motherboard layout on original instructions), you will find every single soldering point on motherboard, so, just go on! :)
4. Now, you can solder and solder! First is good to solder wire interconnections. Then you can solder other components.
5. Another step is about coils holders. I didn't know how to solve this problem. In original, they use special rubber holders. I didn't have them. I used rubber holder from old pen, it works fine. Just look at pictures, it will say everything. :)
6. Finish funcional/electronic part, add some ground wires (on tuning cap for example in my case)
7. Done!..?

Step 6: Assembling





Show All 11 Items

We have already finish, just assemly all parts into the case!

1. I chose solution with screwed mothorboard with frontboard, then frontboard is screwed with case. It's becaouse it is the siplest way for repearing/assembling/disassembling and also, I had not a good tuning cap for this case.
2. Pictures will say the same. :3

Step 7: Final Touches!

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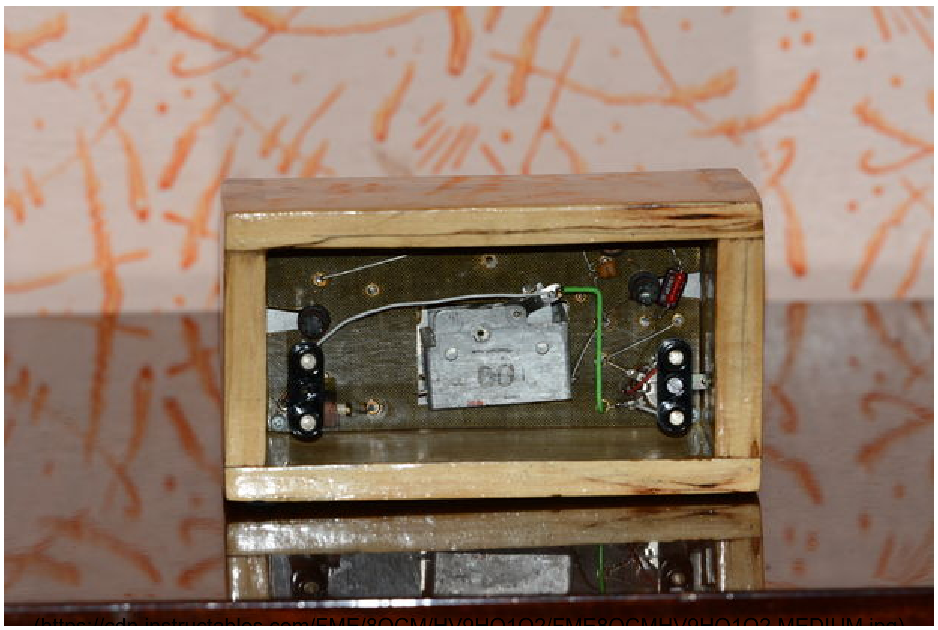

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This is the last step. You can add some buttons on potentiometer, or tuning cap, add some bannana jacks for antenna, ground and headphones and so on. That's only on you!

This is the end! Thanks for your time!

If you like my project, you can support me on facebook https://www.facebook.com/pages/D-Fox/236623253020... (https://www.facebook.com/pages/D-Fox/236623253020320?ref=hl) , or on instagram http://instagram.com/ondrej_fidra (http://instagram.com/ondrej_fidra) .

Respect the nature!

Peace!

Comments

Colaris (/member/Colaris/) 2015-10-18 Reply

Instead of having the antenna drapped around, couldn't THAT be coiled around a tube also?

---

spark master (/member/spark+master/) 2014-05-22 Reply

Oh I fergit, if you have acess to formica or thin slate or anything non conductive you can build right on it. Stuff like this was built on wood, that was shellacked a few times or shellacked then waxed, or might be build on a chunk of (yikes) soapstone or an old tile.

But usually it was wood. As long as it was non ferrous, non conductive and not subject to water retention, it was good to go. On a few I just screwed the components to a block of scrap wood, then put it on an antenna or Arial .

A note on antenni, as ham's will tell you height makes maight and size matters.

The higher you get the antenna or the bigger it is the better it will work. Also if you get your antenna feed up high instead of one wire x feet long use 3 -4 all parallel that will snag more micro volts from the air giving you more energy into the detector circuits and headphones.

And

the better you ground this thing, the better it will work. For a really good ground bury a 1957 GM car (any one will do), at least ten feet below the ground attaching #8 stranded wire to it, back fill with lightly salted sand with a sprinkling of iron filings soak well with salted water and then put finished ground cover, water daily.

If that is unavailable,,,cold water pipes are sufficient.

they don't call me sparkie fer nut'n

DiggingFox (/member/DiggingFox/) ▸ spark master (/member/spark+master/)

Antenna and ground are very important. If you've got better antenna and ground, you've got better sound and selectivity! I've got about 20 meters long antenna in 30 meters, and it's fine (sometimes is very dangerous! when the storm comes!)

2014-05-23 Reply

Thanks for your comments! 73!

spark master (/member/spark+master/) 2014-05-22 Reply

here is a page that has the same jpegs, but can be enlarged enough to read them

http:/ remove this /fmamradios.co remove this m/pics/Miller565-2-3.jpg

I think this version is nicer then the original

DiggingFox (/member/DiggingFox/) ▸ spark master (/member/spark+master/)

2014-05-23 Reply

If you look at the full size of the picture of instruction on this site, you can read them too! :) Thanks you!

spark master (/member/spark+master/) 2014-05-22 Reply

I have built a number of Xtal Radios and they are fun, but where does one purchase old huge variable caps?

You can make them (albeit they may be a tad crappy, or you may need to experiment to get the right capacitance), or if you find old dumped radios you are good to go. It has been years , but I thought the tuner was about 360 MFD's or so. Great project!

DiggingFox (/member/DiggingFox/) ▸ spark master (/member/spark+master/)

2014-05-23 Reply

Thanks! The best way to get the big caps is take it from old damaged radios (don't kill them!! old radios are jewelery!! look at the design!!)...but, this cap has about 300 mmFD on each side, 500 mmFD on each side is better!

manohar (/member/manohar/) 2014-05-20 Reply

could you please provide the circuit diagram for electronics.

DiggingFox (/member/DiggingFox/) ▸ manohar (/member/manohar/) Reply

2014-05-20

Hi! Circuit diagram and schematic is in step 1, in original instructions.

Tommy_tux (/member/Tommy_tux/) 2014-05-20 Reply

Very nice design... Maybe you can build in a web radio? Thanks for this idea...

DiggingFox (/member/DiggingFox/) ▸ Tommy_tux (/member/Tommy_tux/) Reply

2014-05-20

Tkanks you! Yea, I could, I am working on web radio with STM32, but it's too hard for me, I have to learn more about it :)

ASCAS (/member/ASCAS/) 2014-05-19 Reply

Man that sure is awesome!

DiggingFox (/member/DiggingFox/) ▸ ASCAS (/member/ASCAS/) Reply 2014-05-19

Thanks!

Akin Yildiz (/member/Akin+Yildiz/) 2014-05-18 Reply

very nice !

DiggingFox (/member/DiggingFox/) ▸ Akin Yildiz (/member/Akin+Yildiz/) Reply 2014-05-19

Thank you!

mikeasaurus (/member/mikeasaurus/) 2014-05-18 Reply

This looks great. It *wood* be fun to see this in a log cabin

DiggingFox (/member/DiggingFox/) ▸ mikeasaurus (/member/mikeasaurus/) 2014-05-18 Reply

Thanks! Haha, yea it *wood* be :)

plantprof (/member/plantprof/) ▸ DiggingFox (/member/DiggingFox/) Reply 2014-05-18

Nice project and nicely presented. Love your sense of humor and I wish I could communicate as effectively in Czech as you can in English. Enjoyed reading and following your Instructable! I found myself smiling with admiration for what you made, and that you took time to share it here. Did you use that back saw that is visible in the photo to cut the pieces of wood? [That must have been fun!] And where did you you come across the old plans for the radio? [the internet?] How much chocolate is needed! :)

DiggingFox (/member/DiggingFox/) ▸ plantprof (/member/plantprof/) Reply 2014-05-19

Thank you! yes, I used the saw visible on the fotos (with the orange handle), the plans are from the internet, of course :) I am a bit chocoholic, I ate about 10 bars od chocolate :D hope, you like it :)

andrea biffi (/member/andrea+biffi/) 2014-05-18 Reply

cool design!

DiggingFox (/member/DiggingFox/) ▸ andrea biffi (/member/andrea+biffi/) Reply 2014-05-18

Thanks man!

UNIVERSITAT POLITÈCNICA DE CATALUNYA

ERASMUS STUDENT EXCHANGE PROJECT:

DESIGN AND IMPLEMENTATION OF UHF PATCH ANTENNA

ERASMUS STUDENT:

ALEKSANDER SYNAK

SUPERVISOR:

PROFESSOR IGNACIO GIL

Terrassa 2014

Index:

1. Introduction.

This document contains the final report of designing and implementation of a patch antenna, among setting up of dimensions (more information is included in chapter 5.1), comparing results from Momentum Microwave and real measurements, analyzing S_{11} parameters and others. At the beginning it intends to explain what an antenna is. Then, types of antenna and characteristic of patch antenna will be presented. Next chapter is devoted to explain the main parameters of antennas, for example radio patterns, directivity, gain, polarization, efficiency and even measurement techniques. This report contains also tools and methods which have been used to design the specified antenna. Also it describes Feature Selective Validation (FSV) for Validation of Computational Electromagnetic (CEM). Program that was used to designing process is Advance Design System shared by Universitat Politècnica de Catalunya. Last chapter raises the main topic of this report, namely general information about designed antenna, simulation result, measurements, problems and final conclusion. At the end of document bibliography is attached.

2. Antennas.

2.1. What an antenna is?

What is antenna? Answer on that question can be little twisted, but it is justify: Piece of wire is not antenna even ignore that in this wire is flowing current generated by hundreds or thousands transmitters placed in some close area. In other side, when we plug in this wire to radio working on VHF and when it fulfill expectations also make better receiving, then our wire become a antenna.

2.2. Types of antennas.

Now will be introduce and briefly discuss some forms of the various antenna types.

Wire antennas

Wire antennas are familiar to the layman because they are seen virtually everywhere on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are various shapes of wire antennas such as a straight wire (dipole), loop, and helix which are shown in Figure 2.1. Loop antennas need not only be circular. They may take the form of a rectangle, square, ellipse, or any other configuration. The circular loop is the most common because of its simplicity in construction.

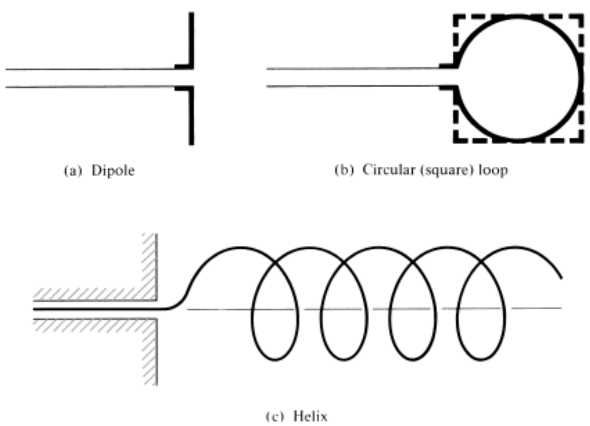
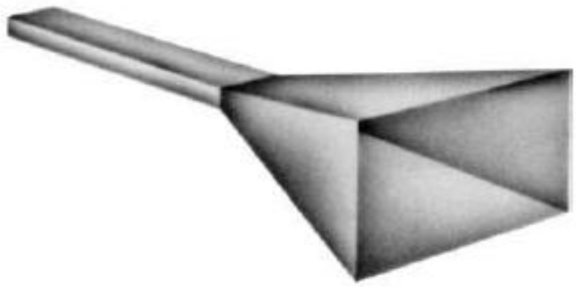


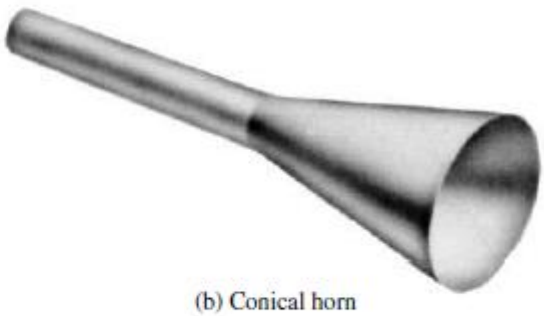
Figure 2.1. Wire antenna configuration.

Aperture antennas

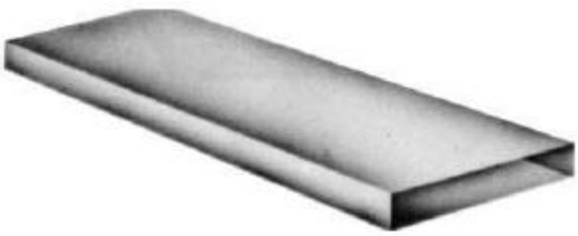
Aperture antennas may be more familiar to the layman today than in the past because of the increasing demand for more sophisticated forms of antennas and the utilization of higher frequencies. Some forms of aperture antennas are shown in Figure 2.2. Antennas of this type are very useful for aircraft and spacecraft applications, because they can be very conveniently flush-mounted on the skin of the aircraft or spacecraft. In addition, they can be covered with a dielectric material to protect them from hazardous conditions of the environment.



(a) Pyramidal horn



(b) Conical horn



(c) Rectangular waveguide

Figure 2.2. Aperture antenna configuration.

Microstrip antennas

Microstrip antennas became very popular in the 1970s primarily for space borne applications. Today they are used for government and commercial applications. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations. However, the rectangular and circular patches, shown in Figure 2.3, are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. The microstrip antennas are low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC (Monolithic Microwave Integrated Circuit)

designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones.

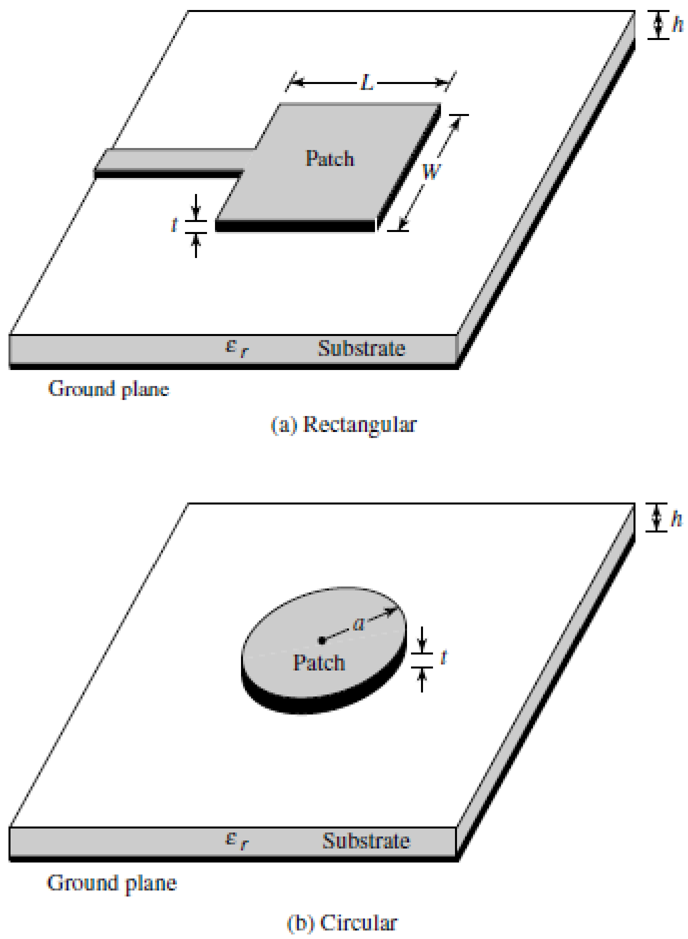


Figure 2.3. Patch antennas.

Array antennas

Many applications require radiation characteristics that may not be achievable by a single element. It may, however, be possible that an aggregate of radiating elements in an electrical and geometrical arrangement (*an array*) will result in the desired radiation characteristics. The arrangement of the array may be such that the radiation from the elements adds up to give a radiation maximum in a particular direction or directions, minimum in others, or otherwise as desired. Typical examples of arrays are shown in Figure 1.6. Usually the term *array* is reserved for an arrangement in which the individual radiators are separate as shown in Figures 2.4(a–c).

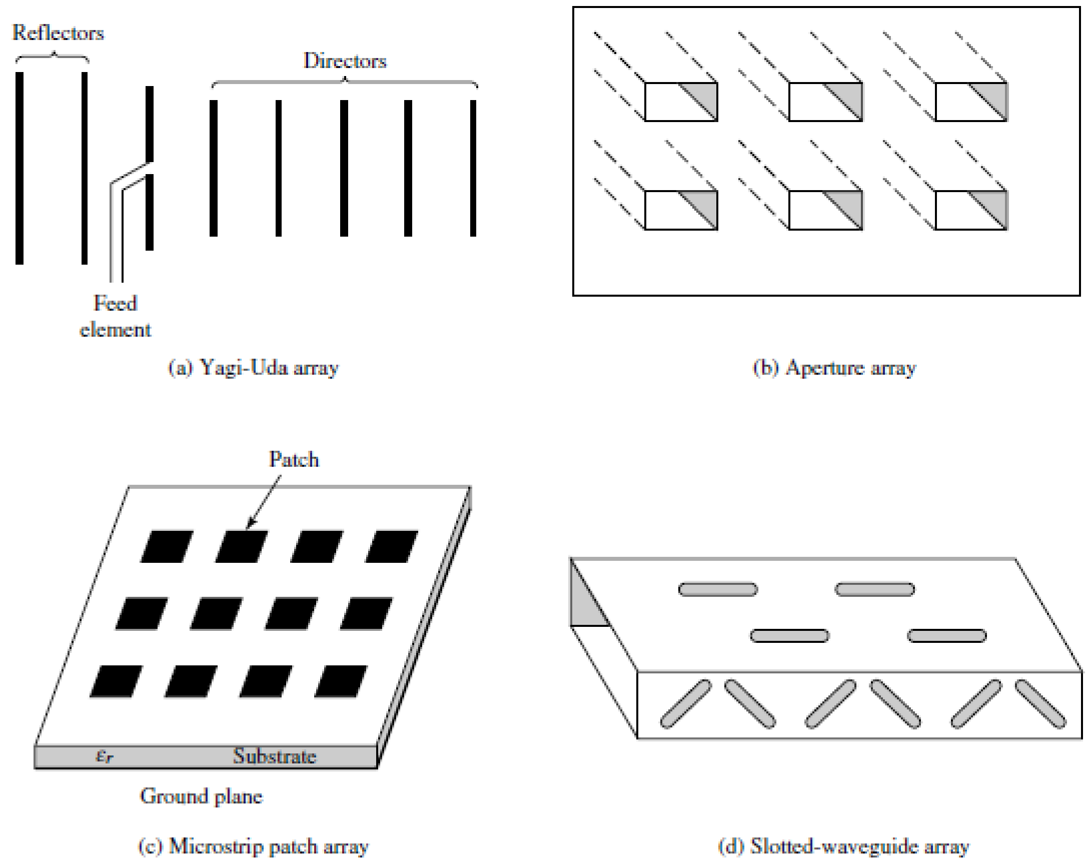


Figure 2.4. Arrays antennas configuration.

Lens antennas

Lenses are primarily used to collimate incident divergent energy to prevent it from spreading in undesired directions. By properly shaping the geometrical configuration and choosing the appropriate material of the lenses, they can transform various forms of divergent energy into plane waves. They can be used in most of the same applications as are the parabolic reflectors, especially at higher frequencies. Their dimensions and weight become exceedingly large at lower frequencies. Lens antennas are classified according to the material from which they are constructed, or according to their geometrical shape. In summary, an ideal antenna is one that will radiate all the power delivered to it from the transmitter in a desired direction or directions. In practice, however, such ideal performances cannot be achieved but may be closely approached. Various types of antennas are available and each type can take different forms in order to achieve the desired radiation characteristics for the particular application.

2.3. Patch antennas.

In high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low-profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications, that have similar specifications. To meet these requirements, patch antennas (microstrip, copolar, etc.) can be used. These antennas are low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with

MMIC designs, and when the particular patch shape and mode are selected, they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed.

Major operational disadvantages of microstrip antennas are their low efficiency, low power, high Q (sometimes in excess of 100), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth, which is typically only a fraction of a percent or at most a few percent. In some applications, such as in government security systems, narrow bandwidths are desirable. However, there are methods, such as increasing the height of the substrate, that can be used to extend the efficiency (to as large as 90 percent if surface waves are not included) and bandwidth (up to about 35 percent). However, as the height increases, surface waves are introduced which usually are not desirable because they extract power from the total available for direct radiation (space waves). The surface waves travel within the substrate and they are scattered at bends and surface discontinuities, such as the truncation of the dielectric and ground plane, and degrade the antenna pattern and polarization characteristics. Surface waves can be eliminated, while maintaining large bandwidths, by using cavities. Stacking, as well as other methods, of microstrip elements can also be used to increase the bandwidth. In addition, microstrip antennas also exhibit large electromagnetic signatures at certain frequencies outside the operating band, are rather large physically at VHF and possibly UHF frequencies, and in large arrays there is a trade-off between bandwidth and scan volume.

Basic characteristics

Microstrip antennas received considerable attention starting in the 1970s, although the idea of a microstrip antenna can be traced to 1953 and a patent in 1955. Microstrip antennas, as shown in Figure 2.5(a), consist of a very thin (t ≡thickness) ($t << \lambda_0$, where λ_0 is the free-space wavelength) metallic strip (patch) placed a small fraction of a wavelength ($h << \lambda_0$, usually $0.003\lambda_0 \le h \le 0.05\lambda_0$) above a ground plane. The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. End-fire radiation can also be accomplished by judicious mode selection. For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$. The strip (patch) and the ground plane are separated by a dielectric sheet (referred to as the substrate), as shown in Figure 2.5(a).

There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 \le \varepsilon_r \le 12$. The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. Thin substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes; however, because of their greater losses, they are less efficient and have relatively smaller bandwidths. Since microstrip antennas are often integrated with other microwave circuitry, a compromise has to be reached between good antenna performance and circuit design.

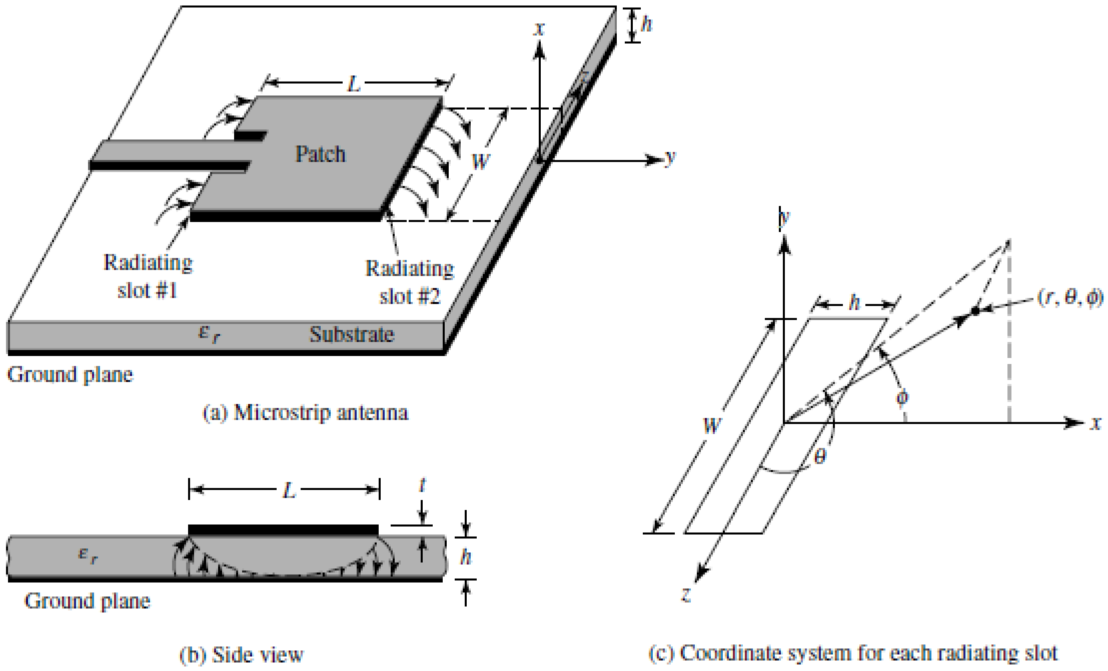


Figure 2.5. Microstrip antenna and coordination system.

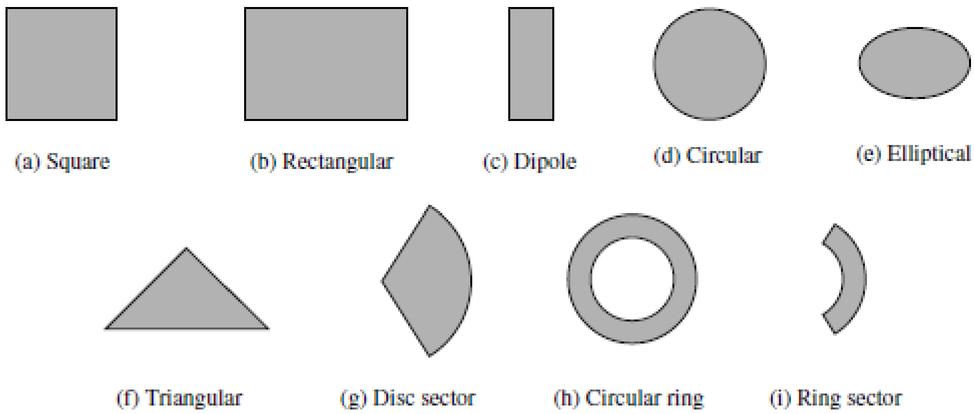


Figure 2.6. Shapes of patchs.

Often microstrip antennas are also referred to as *patch* antennas. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular, or any other configuration. These and others are illustrated in Figure 2.6. Square, rectangular, dipole (strip), and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. Microstrip dipoles are attractive because they inherently possess a large bandwidth and occupy less space, which makes them attractive for arrays. Linear and circular polarizations can be achieved with either single elements or arrays of microstrip antennas. Arrays of microstrip elements, with single or multiple feeds, may also be used to introduce scanning capabilities and achieve greater directivities. These will be discussed in later sections.

3. Antenna parameters.

3.1. Radiation pattern.

An antenna radiation pattern or antenna pattern is defined as "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization." The radiation property of most concern is the two- or three-dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius. A convenient set of coordinates is shown in Figure 3.1. A trace of the received electric (magnetic) field at a constant radius is called the amplitude field pattern. On the other hand, a graph of the spatial variation of the power density along a constant radius is called an amplitude power pattern.

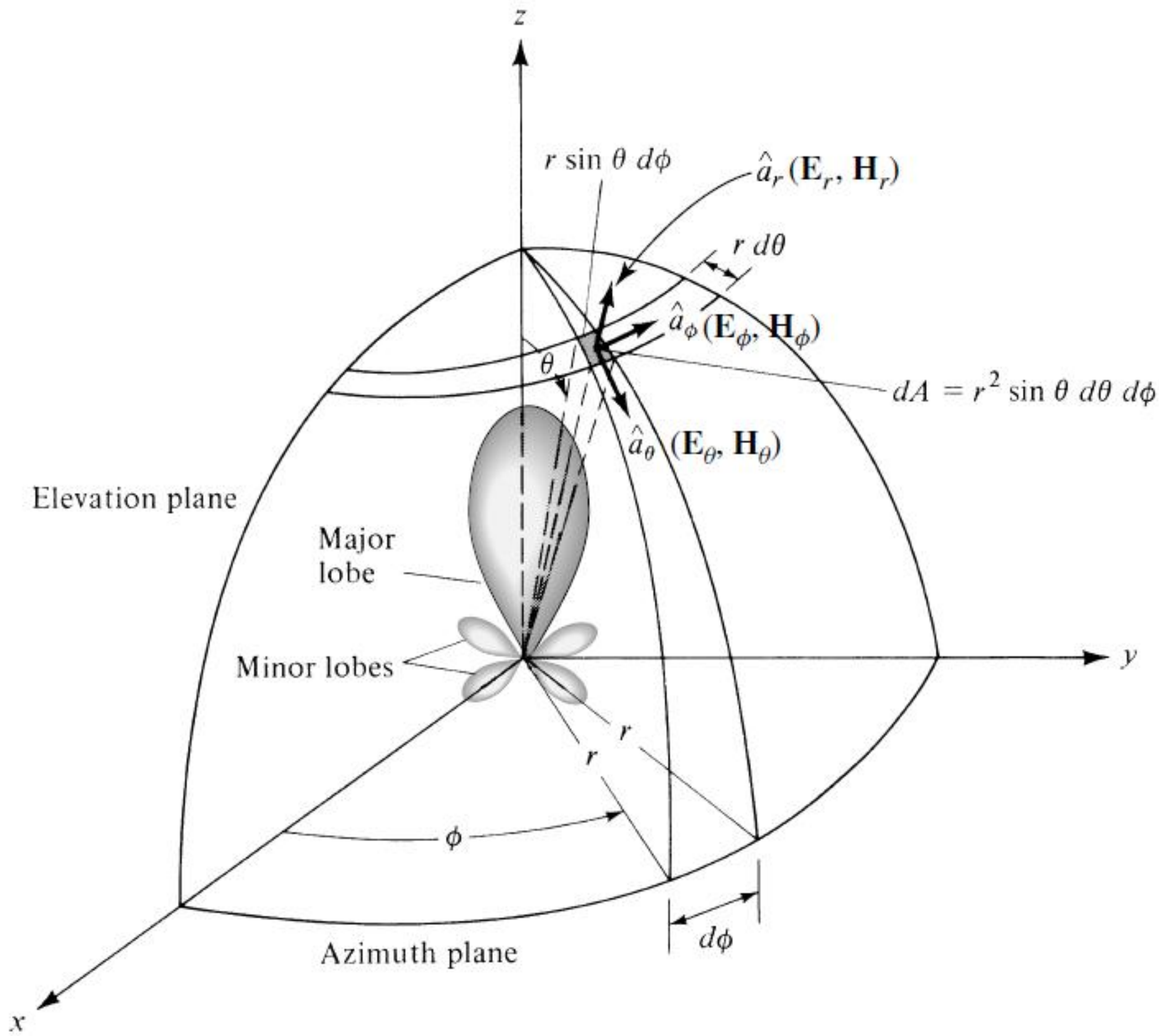


Figure 3.1. Coordinate system for antenna analysis.

Often the field and power patterns are normalized with respect to their maximum value, yielding normalized field and power patterns. Also, the power pattern is usually plotted on a logarithmic scale or more commonly in decibels (dB). This scale is usually desirable because a

logarithmic scale can accentuate in more details those parts of the pattern that have very low values, which later we will refer to as minor lobes. For an antenna, the

a) field pattern(*in linear scale*) typically represents a plot of the magnitude of the electric or magnetic field as a function of the angular space.

b) power pattern(*in linear scale*) typically represents a plot of the square of the magnitude of the electric or magnetic field as a function of the angular space.

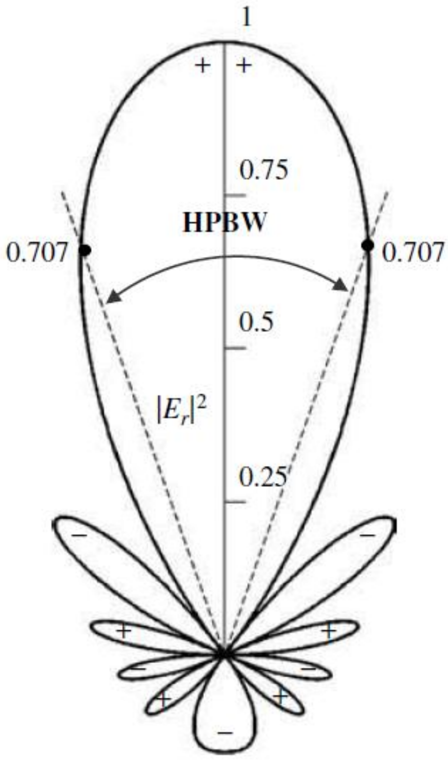
c) power pattern(*in dB*) represents the magnitude of the electric or magnetic field, in decibels, as a function of the angular space.

To demonstrate this, the two-dimensional normalized field pattern (*plotted in linear scale*), power pattern(*plotted in linear scale*), and power pattern (*plotted on a logarithmic dB scale*) of a 10-element linear antenna array of isotropic sources, with a spacing of $d = 0.25\lambda$ between the elements, are shown in Figure 3.2. *In this and subsequent patterns, the plus (+) and minus (−) signs in the lobes indicate the relative polarization of the amplitude between the various lobes, which changes (alternates) as the nulls are crossed*. To find the points where the pattern achieves its half-power (−3 dB points), relative to the maximum value of the pattern, you set the value of the

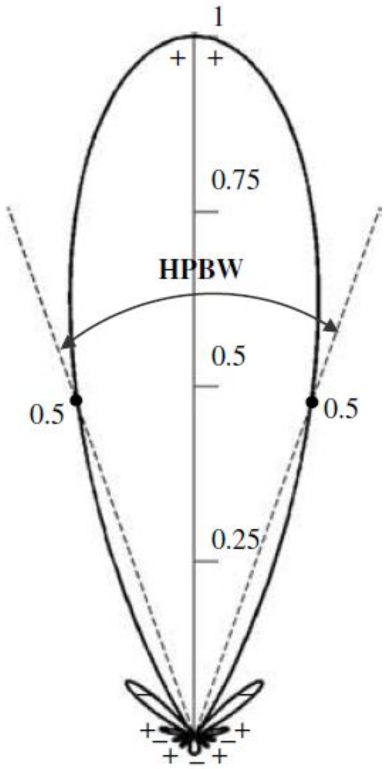
a) field pattern at 0.707 value of its maximum, as shown in Figure 3.2(a)

b) power pattern (in a linear scale) at its 0.5 value of its maximum, as shown in Figure 3.2(b)

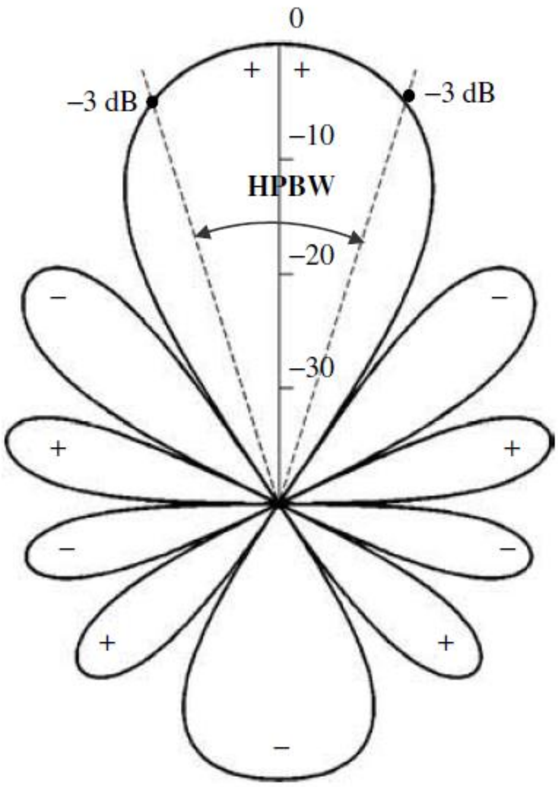
c) power pattern (in dB) at −3 dB value of its maximum, as shown in Figure 3.2(c).



(a) Field pattern (in linear scale)



(b) Power pattern (in linear scale)



(c) Power pattern (in dB)

Figure 3.2. Two-dimensional normalized field pattern(linear scale), power pattern(linear scale), and power pattern(in dB) of a 10-element linear array with a spacing of $d = 0.25\lambda$.

All three patterns yield the same angular separation between the two half-power points, 38.64◦, on their respective patterns, *referred to as HPBW* and illustrated in Figure 3.2.

The *Half-Power Beamwidth* (*HPBW*) is one of the most widely used beamwidths, which is defined by IEEE as: “In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half value of the beam.”

In practice, the three-dimensional pattern is measured and recorded in a series of two-dimensional patterns. However, for most practical applications, a few plots of the pattern as a function of *Θ* for some particular values of *Φ*, plus a few plots as a function of *Φ* for some particular values of *Θ*, give most of the useful and needed information.

3.2. Directivity.

In the 1983 version of the IEEE Standard Definitions of Terms for Antennas, there has been a substantive change in the definition of directivity, compared to the definition of the 1973 version. Basically the term directivity in the new 1983 version has been used to replace the term directive gain of the old 1973 version. In the new 1983 version the term directive gain has been deprecated. According to the authors of the new 1983 standards, “this change brings this standard in line with common usage among antenna engineers and with other international standards, notably those of the International Electrotechnical Commission (IEC).” Therefore directivity of an antenna defined as “the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4*π*. If the direction is not specified, the direction of maximum radiation intensity is implied.” Stated more simply, the directivity of a non-isotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source. In mathematical form, using (3-1),

$$U_0 = \frac{P_{\text{rad}}}{4\pi} \tag{3-1}$$

it can be written as:

$$D = \frac{U}{U_0} = \frac{4\pi U}{P_{\text{rad}}} \tag{3-2}$$

If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity) expressed as

$$D_{\max} = |D_0 = \frac{U|_{\max}}{U_0} = \frac{U_{\max}}{U_0} = \frac{4\pi U_{\max}}{P_{\text{rad}}} \tag{3-2a}$$

D = directivity (dimensionless)

D_0 = maximum directivity (dimensionless)

U = radiation intensity (W/unit solid angle)

U_{max} = maximum radiation intensity (W/unit solid angle)

U_0 = radiation intensity of isotropic source (W/unit solid angle)

P_{rad} = total radiated power (W)

For anisotropic source, it is very obvious from (3-2) or (3-2a) that the directivity is unity since U, U_{max}, an dU_0 are all equal to each other. For antennas with orthogonal polarization components, we define the *partial directivity of an antenna for a given polarization in a given direction* as "that part of the radiation intensity corresponding to a given polarization divided by the total radiation intensity averaged over all directions." With this definition for the partial directivity, then in a given direction "the total directivity is the sum of the partial directivities for any two orthogonal polarizations." For a spherical coordinate system, the total maximum directivity D_0 for the orthogonal Θ and Φ components of an antenna can be written as

$$D_0 = D_\theta + D_\phi \tag{3-3}$$

while the partial directivities D_θ and D_φ are expressed as

$$D_\theta = \frac{4\pi U_\theta}{(P_{\text{rad}})_\theta + (P_{\text{rad}})_\phi} \tag{3-4a}$$

$$D_\phi = \frac{4\pi U_\phi}{(P_{\text{rad}})_\theta + (P_{\text{rad}})_\phi} \tag{3-4b}$$

where,

U_Θ = radiation intensity in a given direction contained in Θ field component

U_Φ = radiation intensity in a given direction contained in Φ field component

$(P\text{rad})_\Theta$ = radiated power in all directions contained in Θ field component

$(P\text{rad})_\Phi$ = radiated power in all directions contained in Φ field component

3.3. Antenna efficiency.

Associated with an antenna are a number of efficiencies and can be defined using Figure 3.3. The total antenna efficiency $e0$ is used to take into account losses at the input terminals and within the structure of the antenna. Such losses may be due, referring to Figure 3.3(b), to

1. reflections because of the mismatch between the transmission line and the antenna

2. I 2R losses (conduction and dielectric)

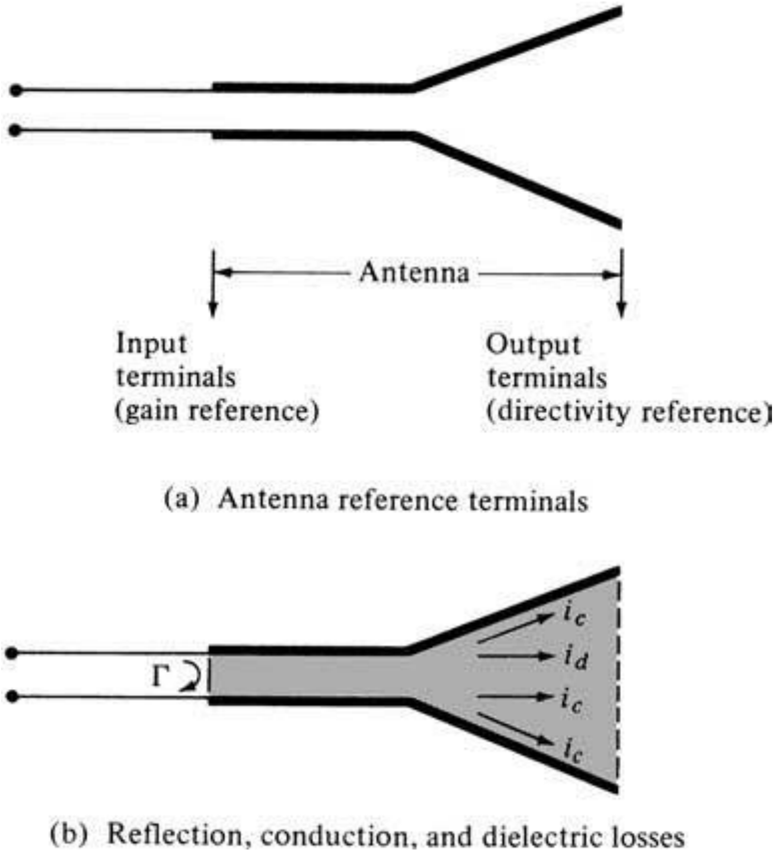


Figure 3.3. Reference terminals and losses of an antenna.

In general, the overall efficiency can be written as

$$e_0 = e_r e_c e_d \tag{3-5}$$

where

e_0 = total efficiency (dimensionless)
e_r = reflection(mismatch) efficiency = $(1 - |\Gamma|^2)$ (dimensionless)
e_c = conduction efficiency (dimensionless)
e_d = dielectric efficiency (dimensionless)
Γ = voltage reflection coefficient at the input terminals of the antenna
[$\Gamma = (Z_{in} - Z_0)/(Z_{in} + Z_0)$ where Z_{in} = antenna input impedance,
$Z0$ = characteristic impedance of the transmission line]

$$\text{VSWR} = \text{voltage standing wave ratio} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Usually e_c and e_d are very difficult to compute, but they can be determined experimentally. Even by measurements they cannot be separated, and it is usually more convenient to write (3-5) as

$$e_0 = e_r e_{cd} = e_{cd}(1 - |\Gamma|^2) \tag{3-6}$$

where $e_{cd} = e_c e_d$ = antenna radiation efficiency, which is used to relate the gain and directivity.

3.4. Gain.

Another useful measure describing the performance of an antenna is the *gain*. Although the gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Remember that directivity is a measure that describes only the directional properties of the antenna, and it is therefore controlled only by the pattern.

Gain of an antenna (in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π." In equation form this can be expressed as

$$\text{Gain} = 4\pi \frac{\text{radiation intensity}}{\text{total input (accepted) power}} = 4\pi \frac{U(\theta, \phi)}{|P_{in}} \quad \text{(dimensionless)} \tag{3-7}$$

In most cases we deal with *relative gain*, which is defined as "the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction." The power input must be the same for both antennas. The reference antenna is usually a dipole, horn, or any other antenna whose gain can be calculated or it is known. In most cases, however, the reference antenna is a *lossless isotropic source*. Thus

$$G = \frac{4\pi U(\theta, \phi)}{P_{in}\text{(lossless isotropic source)}} \quad \text{(dimensionless)} \tag{3-7a}$$

When the direction is not stated, the power gain is usually taken in the direction of maximum radiation.

Referring to Figure 3.1(a), we can write that the total radiated power *(P_{rad})* is related to the total input power *(P_{in})* by

$$P_{\text{rad}} = e_{cd} P_{in} \tag{3-9}$$

where e_{cd} is the antenna radiation efficiency (dimensionless) which is defined in (3-5), (3-6). According to the IEEE Standards, "gain does not include losses arising from impedance mismatches (reflection losses) and polarization mismatches (losses)."

In this document we define two gains; one, referred to as *gain* (G), and the other, referred to as *absolute gain (Gabs)*, that also takes into account the reflection/mismatch losses represented in both (3-5) and (3-6). Using (3-9) reduces (3-7a) to

$$G(\theta,\phi) = e_{cd}\left[4\pi\frac{U(\theta,\phi)}{P_{\text{rad}}}\right] \tag{3-10}$$

which is related to the directivity of (3-2) by

$$G(\theta,\phi) = e_{cd}D(\theta,\phi) \tag{3-11}$$

In a similar manner, the maximum value of the gain is related to the maximum directivity of (3-2a) by

$$G_0 = G(\theta,\phi)|_{\max} = e_{cd}D(\theta,\phi)|_{\max} = e_{cd}D_0 \tag{3-11a}$$

While (3-9) does take into account the losses of the antenna element itself, *it does not take into account the losses when the antenna element is connected to a transmission line*, as shown in Figure 3.1. These connection losses are usually referred to as *reflections (mismatch) losses*, and they are taken into account by introducing a reflection(mismatch) efficiency e_r , which is related to the reflection coefficient as shown in (3-6) or $e_r = (1 - |\Gamma|^2)$. Thus, we can introduce an *absolute gain* G_{abs} that takes into account the reflection/mismatch losses (due to the connection of the antenna element to the transmission line), and it can be written as

$$\begin{aligned} G_{abs}(\theta,\phi) &= e_r G(\theta,\phi) = (1-|\Gamma|^2)G(\theta,\phi) \\ &= e_r e_{cd} D(\theta,\phi) = e_o D(\theta,\phi) \end{aligned} \tag{3-12}$$

where e_o is the overall efficiency as defined in (3-6), (3-7). Similarly, the *maximum absolute* gain G_{0abs} of (3-11a) is related to the maximum directivity D_0 by

$$\begin{aligned} G_{0abs} &= G_{abs}(\theta,\phi)|_{\max} = e_r G(\theta,\phi)|_{\max} = (1-|\Gamma|^2)G(\theta,\phi)|_{\max} \\ &= e_r e_{cd} D(\theta,\phi)|_{\max} = e_o D(\theta,\phi)|_{\max} = e_o D_0 \end{aligned} \tag{3-13}$$

If the antenna is matched to the transmission line, that is, the antenna input impedance Z_{in} is equal to the characteristic impedance Z_c of the line ($|\Gamma| = 0$), then the two gains are equal ($G_{abs} = G$).

As was done with the directivity, we can define the *partial gain of an antenna for a given polarization in a given direction* as "that part of the radiation intensity corresponding to a given polarization divided by the total radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically." With this definition for the partial gain, then, in a given direction, "the total gain is the sum of the partial gains for any two orthogonal polarizations." For a spherical

coordinate system, the total maximum gain G_0 for the orthogonal Θ and Φ components of an antenna can be written, in a similar form as was the maximum directivity in (3-3)–(3-4b), as

$$G_0 = G_\theta + G_\phi \tag{3-14}$$

while the partial gains G_Θ and G_Φ are expressed as

$$G_\theta = \frac{4\pi U_\theta}{P_{in}} \tag{3-14a}$$

$$G_\phi = \frac{4\pi U_\phi}{P_{in}} \tag{3-14b}$$

where
U_Θ = radiation intensity in a given direction contained in E_Θ field component
U_Φ = radiation intensity in a given direction contained in E_Φ field component
P_{in} = total input (accepted) power

3.5. Bandwidth.

The *bandwidth* of an antenna is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." The bandwidth can be considered to be the range of frequencies, on either side of a center frequency (usually the resonance frequency for a dipole), where the antenna characteristics (such as input impedance, pattern, beamwidth, polarization, side lobe level, gain, beam direction, radiation efficiency) are within an acceptable value of those at the center frequency. For broadband antennas, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation. For example, a 10:1 bandwidth indicates that the upper frequency is 10 times greater than the lower. For narrowband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency of the bandwidth. For example, a 5% bandwidth indicates that the frequency difference of acceptable operation is 5% of the center frequency of the bandwidth.

Because the characteristics (input impedance, pattern, gain, polarization, etc.) of an antenna do not necessarily vary in the same manner or are even critically affected by the frequency, there is no unique characterization of the bandwidth. The specifications are set in each case to meet the needs of the particular application. Usually there is a distinction made between pattern and input impedance variations. Accordingly *pattern bandwidth* and *impedance bandwidth* are used to emphasize this distinction. Associated with pattern bandwidth are gain, side lobe level, beamwidth, polarization, and beam direction while input impedance and radiation efficiency are related to impedance bandwidth. For example, the pattern of a linear dipole with overall length less than a half-wavelength $(l < \lambda/2)$ is insensitive to frequency. The limiting factor for this antenna is its impedance, and its bandwidth can be formulated in terms of the Q. The Q of antennas or arrays with dimensions large compared to the wavelength, excluding superdirective designs, is near unity. Therefore the bandwidth is usually formulated in terms of beamwidth, side lobe level, and pattern characteristics. For intermediate length antennas, the bandwidth may be limited by either pattern or impedance variations, depending upon the

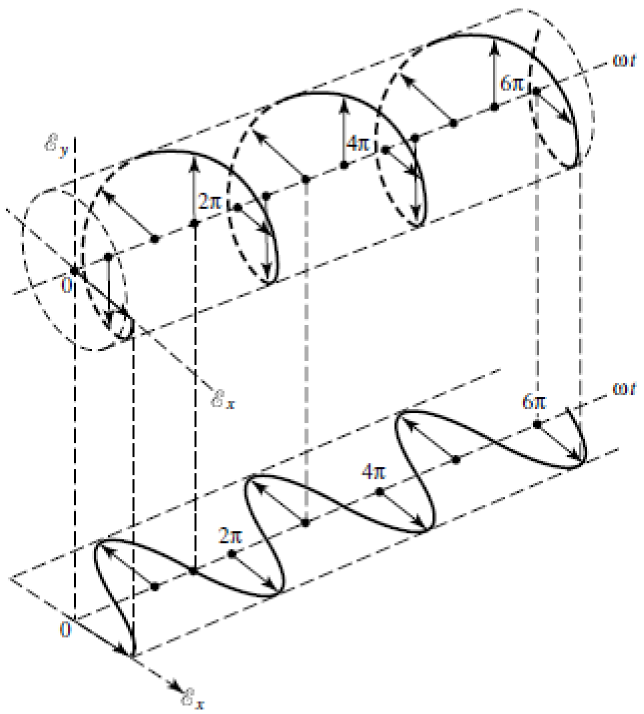
particular application. For these antennas, a 2:1 bandwidth indicates a good design. For others, large bandwidths are needed. Antennas with very large bandwidths (like 40:1 or greater) have been designed in recent years.

The above discussion presumes that the coupling networks (transformers, baluns, etc.) and/or the dimensions of the antenna are not altered in any manner as the frequency is changed. It is possible to increase the acceptable frequency range of a narrowband antenna if proper adjustments can be made on the critical dimensions of the antenna and/or on the coupling networks as the frequency is changed. Although not an easy or possible task in general, there are applications where this can be accomplished. The most common examples are the antenna of a car radio and the “rabbit ears” of a television. Both usually have adjustable lengths which can be used to tune the antenna for better reception.

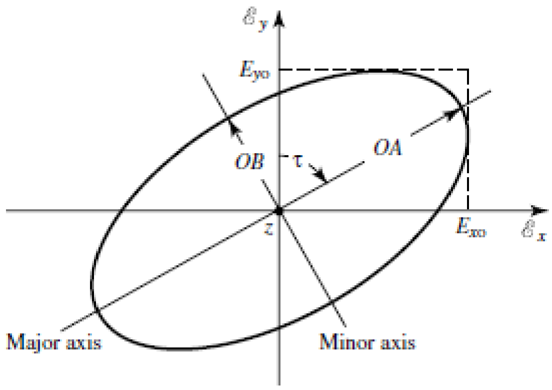
3.6. Polarization.

Polarization of an antenna in a given direction is defined as “the polarization of the wave transmitted (radiated) by the antenna. *Note:* When the direction is not stated, the polarization is taken to be the polarization in the direction of maximum gain.” In practice, polarization of the radiated energy varies with the direction from the center of the antenna, so that different parts of the pattern may have different polarizations.

Polarization of a radiated wave is defined as “that property of an electromagnetic wave describing the time-varying direction and relative magnitude of the electric-field vector; specifically, the figure traced as a function of time by the extremity of the vector at a fixed location in space, and the sense in which it is traced, *as observed along the direction of propagation*.” Polarization then is the curve traced by the end point of the arrow (vector) representing the instantaneous electric field. The field must be observed along the direction of propagation. A typical trace as a function of time is shown in Figures 3.4(a) and (b).



(a) Rotation of wave



(b) Polarization ellipse

Figure 3.4. Rotation of a plane electromagnetic wave and its polarization ellipse at z = 0 as a function of time.

The polarization of a wave can be defined in terms of a wave *radiated (transmitted)* or *received* by an antenna in a given direction. The polarization of a wave *radiated* by an antenna in a specified direction at a point in the far field is defined as "the polarization of the (locally) plane wave which is used to represent the radiated wave at that point. At any point in the far field of an antenna the radiated wave can be represented by a plane wave whose electric-field strength is the same as that of the wave and whose direction of propagation is in the radial direction from the antenna. As the radial distance approaches infinity, the radius of curvature of the radiated wave's phase front also approaches infinity and thus in any specified direction the wave appears locally as a plane wave." The polarization of a wave *received* by an antenna is defined as the "polarization of a plane wave, incident from a given direction and having a given power flux density, which results in maximum available power at the antenna terminals."

Polarization may be classified as linear, circular, or elliptical. If the vector that describes the electric field at a point in space as a function of time is always directed along a line, the field is said to be *linearly* polarized. In general, however, the figure that the electric field traces is an ellipse, and the field is said to be elliptically polarized. Linear and circular polarizations are special cases of elliptical, and they can be obtained when the ellipse becomes a straight line or a circle, respectively. The figure of the electric field is traced in a *clockwise* (CW) or *counterclockwise* (CCW) sense. *Clockwise* rotation of the electric-field vector is also designated as *right-hand polarization* and *counterclockwise* as *left-hand polarization*.

In general, the polarization characteristics of an antenna can be represented by its *polarization pattern* whose one definition is "the spatial distribution of the polarizations of a field vector excited (radiated) by an antenna taken over its radiation sphere. When describing the polarizations over the radiation sphere, or portion of it, reference lines shall be specified over the sphere, in order to measure the tilt angles (see tilt angle) of the polarization ellipses and the direction of polarization for linear polarizations. An obvious choice, though by no means the only one, is a family of lines tangent at each point on the sphere to either the θ or φ coordinate line associated with a spherical coordinate system of the radiation sphere. At each point on the radiation sphere the polarization is usually resolved into a pair of orthogonal polarizations, the *co-polarization* and *cross polarization*. To accomplish this, the co-polarization must be specified at each point on the radiation sphere." "*Co-polarization* represents the polarization the antenna is intended to radiate (receive) while *cross-polarization* represents the polarization orthogonal to a specified polarization, which is usually the co-polarization."

"For certain linearly polarized antennas, it is common practice to define the copolarization in the following manner: First specify the orientation of the co-polar electric-field vector at a pole of the radiation sphere. Then, for all other directions of interest (points on the radiation sphere), require that the angle that the co-polar electric-field vector makes with each great circle line through the pole remain constant over that circle, the angle being that at the pole."

"In practice, the axis of the antenna's main beam should be directed along the polar axis of the radiation sphere. The antenna is then appropriately oriented about this axis to align the direction of its polarization with that of the defined co-polarization at the pole." "This manner of defining co-polarization can be extended to the case of elliptical polarization by defining the constant angles using the major axes of the polarization ellipses rather than the co-polar electric-field vector. The sense of polarization (rotation) must also be specified."

The polarization of the wave radiated by the antenna can also be represented on the Poincar´e sphere. Each point on the Poincar´e sphere represents a unique polarization. The north pole represents left circular polarization, the south pole represents right circular, and points along the equator represent linear polarization of different tilt angles.

3.7. Input impedance.

Input impedance is defined as "the impedance presented by an antenna at its terminals or the ratio of the voltage to current at a pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point." In this section we are primarily interested in the input impedance at a pair of terminals which are the input terminals of the antenna. In Figure 3.5(a) these terminals are designated as $a - b$. The ratio of the voltage to current at these terminals, with no load attached, defines the impedance of the antenna as

$$Z_A = R_A + jX \tag{3-15}$$

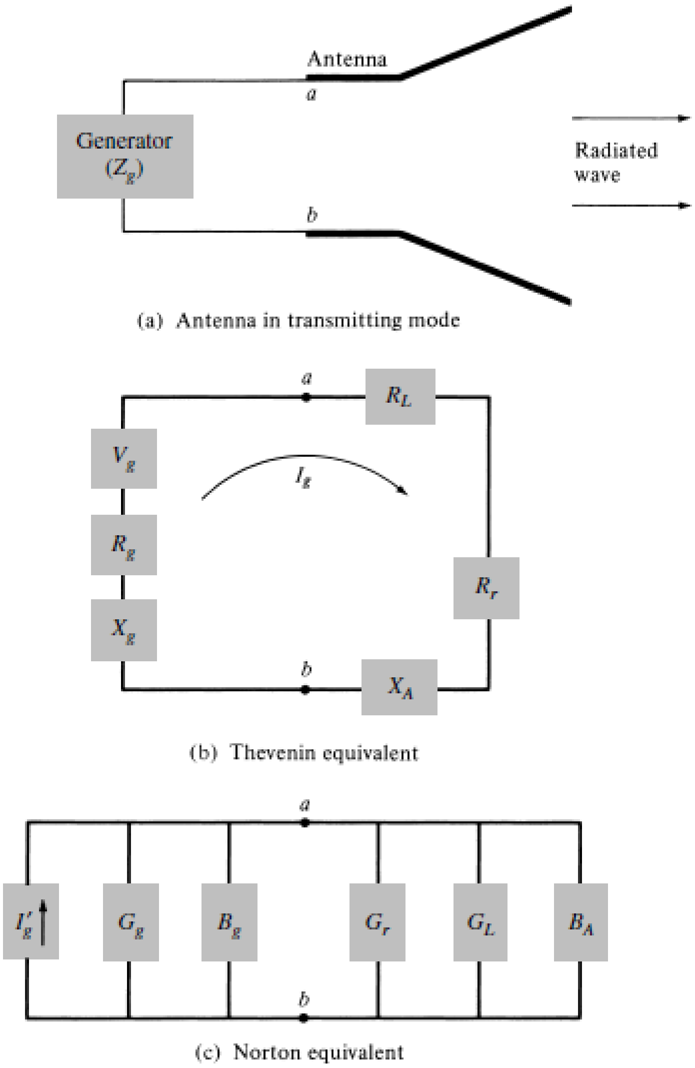


Figure 3.5. Transmitting antenna and its equivalent circuits.

where

Z_A = antenna impedance at terminals *a* –*b* (ohms)

R_A = antenna resistance at terminals *a* –*b* (ohms)

X_A = antenna reactance at terminals *a* –*b* (ohms)

In general the resistive part of (3-15) consists of two components; that is

$$R_A = R_r + R_L \tag{3-16}$$

where

R_r = radiation resistance of the antenna

R_L = loss resistance of the antenna

3.8. S_{11} parameters on Smith chart.

The Smith chart, invented by Phillip H. Smith (1905–1987) is a graphical aid or nomogram designed for electrical and electronics engineers specializing in radio frequency (RF) engineering to assist in solving problems with transmission lines and matching circuits. Use of the Smith chart utility has grown steadily over the years and it is still widely used today, not only as a problem solving aid, but as a graphical demonstrator of how many RF parameters behave at one or more frequencies, an alternative to using tabular information. The Smith chart can be used to simultaneously display multiple parameters including impedances, admittances, reflection coefficients, S_{nn} scattering parameters, noise figure circles, constant gain contours and regions for unconditional stability, including mechanical vibrations analysis. The Smith chart is most frequently used at or within the unity radius region. However, the remainder is still mathematically relevant, being used, for example, in oscillator design and stability analysis.

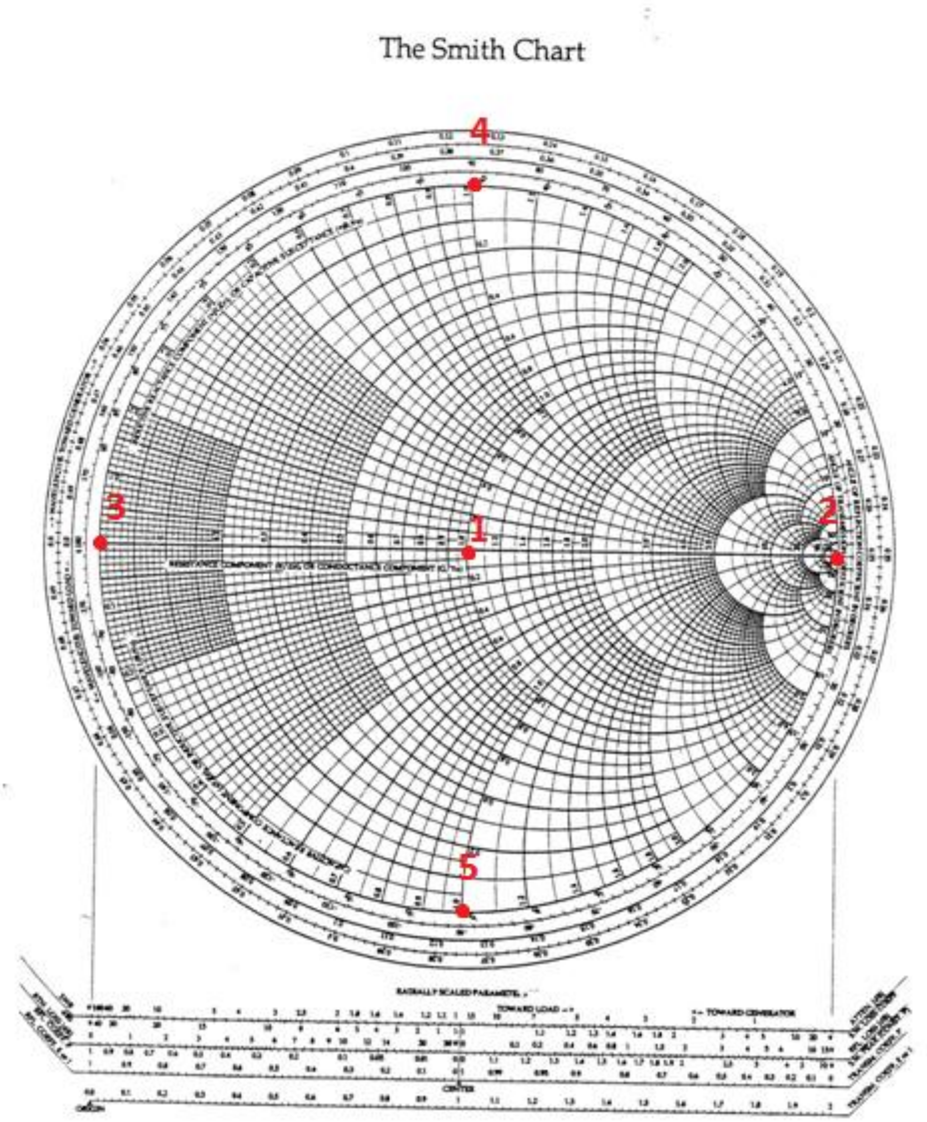


Figure 3.6. Smith chart.

Figure 3.6 shown Smith chart with the most important points:

1) ideal adjustment

2) open circuit

3) short circuit

4) clean inductance

5) clean capacity

3.9. Antenna measurement techniques.

In practice, the most commonly quoted parameter in regards to antennas is S_{11}. S_{11} represents how much power is reflected from the antenna, and hence is known as the reflection coefficient (sometimes written as gamma: Γ or return loss). If S_{11}=0 dB, then all the power is reflected from the antenna and nothing is radiated. If S_{11} = -10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power. The remainder of the power was "accepted by" or delivered to the antenna. This accepted power is either radiated or absorbed as losses within the antenna. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to the antenna is radiated.

Next measurement technique is a radiation pattern. A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field.

Antenna measurements were made by using Agilent FieldFox handheld microwave analyzer N9916A shown in Figure 3.7. Frequency range of this device is 30 kHz - 14 GHz, work temperature is from -10 to 55 C degree, input impedance is 50 Ω (nominal). FieldFox N9916A was using to make a realistic S_{11} parameter of produced antenna on Smith chart and magnitude plot. To synchronize measurement device used Agilent CalKit 85521A with input impedance 50 Ω (figure 3.8).

Figure 3.7. Agilent Technologies FieldFox microwave analyzer N9916A.

Figure 3.8. Agilent Technologies CalKit 85521A.

4. Tools and methods.

4.1. ADS.

We have used Advanced Design System (ADS) as a software in order to made a simulations of antennas. ADS is an electronic design automation software system produced by Agilent EEsof EDA, a unit of Agilent Technologies. It provides an integrated design environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, radar systems, and high-speed data links.

Agilent ADS supports every step of the design process—schematic capture, layout, frequency-domain and time-domain circuit simulation, and electromagnetic field simulation—allowing the engineer to fully characterize and optimize an RF design without changing tools.

Agilent EEsof has donated copies of the ADS software to the electrical engineering departments at many universities, and a large percentage of new graduates are experienced in its use. As a result, the system has found wide acceptance in industry.

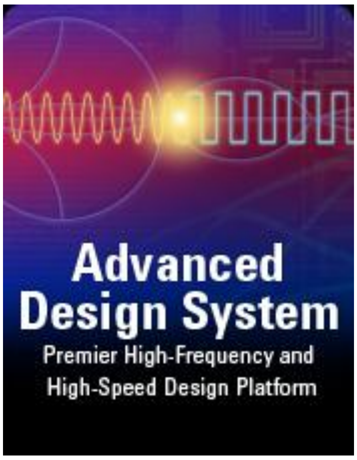


Figure 4.1. Agilent Technologies ADS logo.

Momentum Microwave Simulation

Method of moments estimation is based solely on the law of large numbers. Let M_1, M_2,... be independent random variables having a common distribution possessing a mean μ_M. Then the sample means converge to the distributional mean as the number of observations increase.

$$\bar{M}_n = \frac{1}{n}\sum_{i=1}^{n} M_i \to \mu_M \quad \text{as } n \to \infty.$$

Momentum is a part of Advanced Design System and gives you the simulation tools you need to evaluate and design modern communications systems products. Momentum is an electromagnetic simulator that computes S-parameters for general planar circuits, including microstrip, slotline, stripline, coplanar waveguide, and other topologies. Vias and airbridges connect topologies between layers, so you can simulate multilayer RF/microwave printed circuit boards, hybrids, multichip

modules, and integrated circuits. Momentum gives you a complete tool set to predict the performance of high-frequency circuit boards, antennas, and ICs.

Momentum Optimization extends Momentum capability to a true design automation tool. The Momentum Optimization process varies geometry parameters automatically to help you achieve the optimal structure that meets the circuit or device performance goals. By using (parameterized) layout components you can also perform Momentum optimizations form the schematic page.

Momentum Visualization is an option that gives users a 3-dimensional perspective of simulation results, enabling you to view and animate current flow in conductors and slots, and view both 2D and 3D representations of far-field radiation patterns.

4.2. FSV.

Given that correlation lacked sensitivity for the visually complex data typical to EMC validation and the overall poor response of reliability functions to EMC validation, the FSV method was developed, which approached the task of validation using a reliability function-like approach but basing the general structure of the FSV within the context of the psychology of visual perception.

The FSV method is based on the decomposition of the original data into two parts: amplitude (trend/envelope) data and feature data. The former component accounts for the slowly varying data across the dataset and the latter accounts for the sharp peaks and troughs often found in EMC data. In response to the six applicability tests, the output of FSV can be viewed with a number of different levels of granularity. Specifically, these are as follows.

1) *Global difference measure (GDM).* This is an overall single-figure goodness-of-fit between the two datasets being compared. This allows a simple decision to be made about the quality of a comparison. This may be numerical or converted to a natural language descriptor (excellent, very good, good, fair, poor, very poor). This is obtained from the overall figures for the two components, the amplitude difference measure (ADM), and the feature difference measure (FDM).

2) *ADM and FDM.* These are similarly available as a numerical value or converted to a natural language descriptor as for the GDM. These single-figure goodness-of-fit values combine to give the GDM.

3) *GDMi ,ADMi, andFDMi* . These are point-by-point comparisons of the amplitude differences, the feature differences, and the global difference. These allow users to analyze the resulting data in some detail, particularly with the aim of understanding the origin of the contributors to poor comparisons.

4) *GDMc ,ADMc, andFDMc* . These give a probability density function that shows the proportion of the point-by point analyses of each of the components that falls into the six natural language descriptor categories. This provides a measure of confidence in the single-figure comparisons.

FSV implementation involves interpolating the two datasets to be compared over a common window (often common frequency range or time window) to ensure that the data points to be compared are coincident. This approach ensures that like is being compared with like and will not

affect the overall results unless the data are severely under sampled. It must be remembered that the purpose of the FSV is to mimic a visual comparison, and so long as any interpolation does not produce results that are clearly visually different from the original data, the approach is perfectly acceptable.

As noted above, the actual comparison is based on decomposing the original data into trend information and feature information. Hence, the next step is to Fourier Transform the data and filter the transformed data to separate out the lower and higher frequency portions. These “high” and “low” portions are then transformed back into the original domain. Combinations of these filtered datasets and their derivatives are used to compute the ADM and the FDM, which can be combined into the GDM.

In order to provide a close agreement with visual assessment, FSV is a heuristic technique, with a number of weighting factors and constants that have been obtained by a process of analysis against visual interpretation.

FSV method show that a straight forward mathematical approach can be used to obtain a comparison between two sets of data that is consistent with the interpretation of a group of experts.

In order for a mathematical technique to succeed in performing this function, a number of applicability tests were proposed. The assessment of the FSV method is very positive, suggesting that it is close to achieving these tests.

1) *Implementation of the validation technique should be simple.* The FSV method has been implemented in Java, and using Matlab, it has also been implemented as a MathCad worksheet. Other than a Fourier Transform, no esoteric mathematics or convoluted programming is required.

2) *The technique should be computationally straightforward.* The FSV method has been run on Pentium II-based PCs (and higher).

3) *The technique should mirror human perceptions and should be largely intuitive*. Results to date are very encouraging and will be reported further in Part II.

4) *The method should not be limited to data from a single application area*. Although not discussed in this paper, the FSV method has been successfully used with DNA “fingerprint” data.

5) *The technique should provide tiered diagnostic information*. The output ranging from the GDM (single value) through to the point-by-point analysis and the confidence limits suggest that tiered diagnostics are available.

6) *The comparison should be commutative.* It can be seen from the mathematics involved that the approach is commutative.

The method, seems to come close to providing the bridge between simple data analysis and the more subtle, but more desirable, human interpretation.

5. Project - Design and implementation patch antenna : Inverted F-Antenna (*IFA*) on 868 MHz.

5.1. General information.

This chapter describes my projected antenna. This is a patch antenna and working on frequency 868 MHz (λ = 0.345 m), feed by microstrip line with input impedance 50 Ω. Shape of radiation part is IFA (*Inverted-F Antenna*). Antenna is produced on PCB (*Printed Circuit Board*). Used dielectric is FR4 with thickens 1.53 mm. Permittivity of FR4 is ε_r = 4.5. The dimensions of antenna are written below on Figure 5.1 and Table 5.1. Main idea of shape of antenna was taken from Texas Instruments Design Note DN023. Power supply is 3 V.

Dimensions in this document is a final. Before that, there was a many tries of changing dimensions from original Texas antenna. Compare with Texas Instruments, radiation stripe is cut off almost 20 % of all length. This operation was necessary to match frequency. Second problem was in microstrip. When frequency was right, the S_{11} parameter was on -7 dB and to increase that, the microstrip have is longer 5 mm then original from Texas. Also via is added, because in original design short between F-shape radiation part and ground plane had different solution appear from construction of PCB. Thickness of FR4 was also different, but that was a little problem. The last problem is in feed point. That appear also from construction and to get done with it, We added a coaxial wire which sticking out of PCB.

In our example, IFA have omni radiation. To manipulate frequency You have to change length of radiation stripe. If You increase length of this tripe, the frequency is going up, when You cut of strip, frequency goes down. To make better S_{11} parameters You must manipulate length of microstrip. You can't forget about permittivity of used dielectric. In our case manufactured antenna is better than simulated. One of reasons of this is attached solid coax to antenna. This probably make batter S_{11} parameter about 1.5 dB. Wires plugged in to antenna which is working on UHF, must have a solid attached to case of device to avoid a frequency surfing.

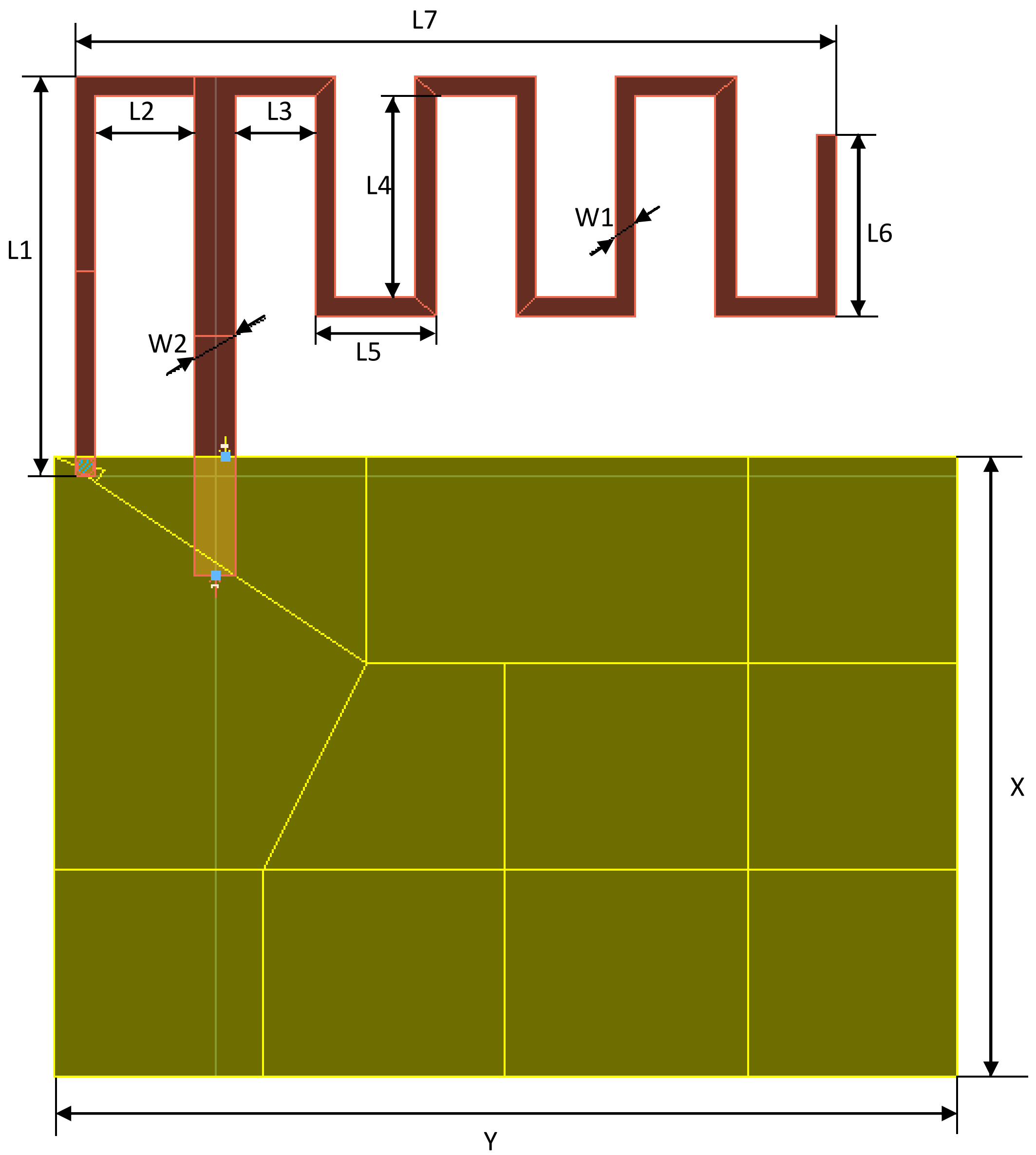


Figure 5.1. Antenna dimensions.

Table 5.1. Antenna dimensions.

L1	20 mm	**X**	31 mm
L2	5 mm	**Y**	45 mm
L3	4 mm	**W1**	1 mm
L4	10 mm	**W2**	2 mm
L5	6 mm		
L6	9 mm		
L7	38 mm		

On Figure 5.1 red color define the top layer (radiation part), yellow define the ground plane and blue striped circle is a via. Length of feed microstrip is 25 mm.

Figure 5.2 shows substrate taken from ADS. "cond" represents top layer, "cond 2" represents bottom layer (*GND*), "hole" represents via. All conductor layers were made from cooper with thickens 45 µm (also during the simulations in ADS).

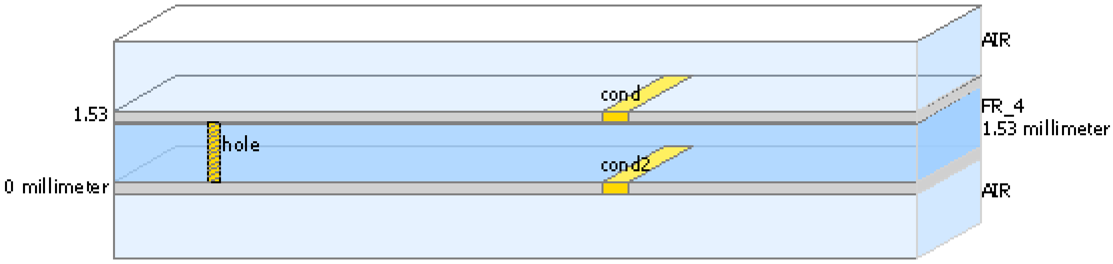


Figure 5.2. Substrate.

Produced antenna shown in Figure 5.3. As You can see, the feed point is made by coaxial wire with plug.

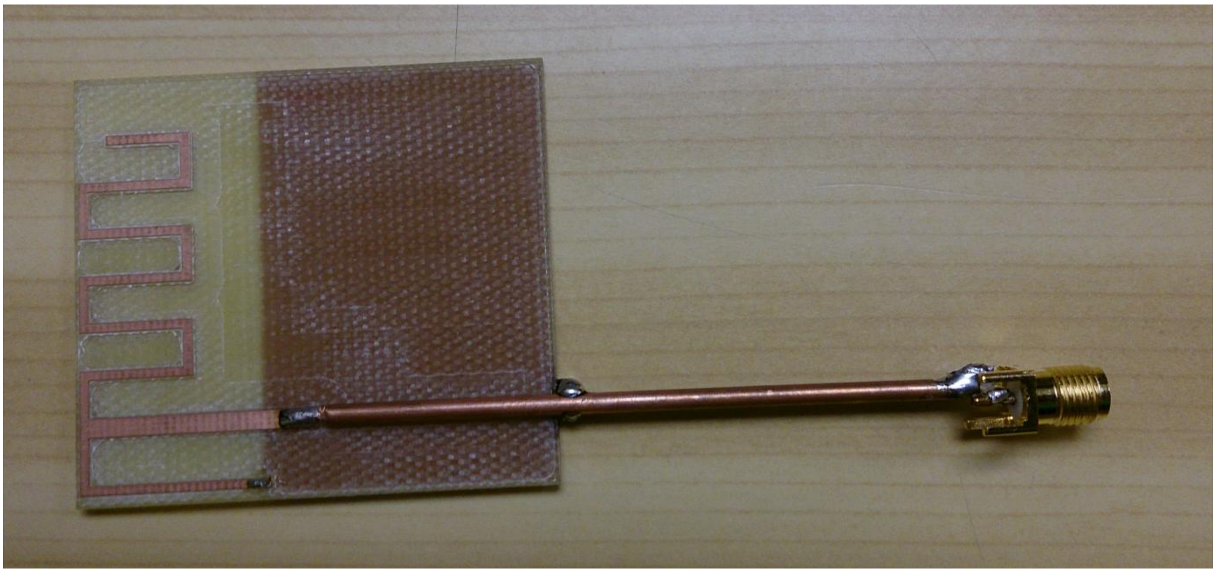


Figure 5.3. Produced IFA.

5.2. Momentum microwave simulation.

In this subchapter will be presented a simulations taken from ADS - S_{11} parameters, far fields, radiation pattern.

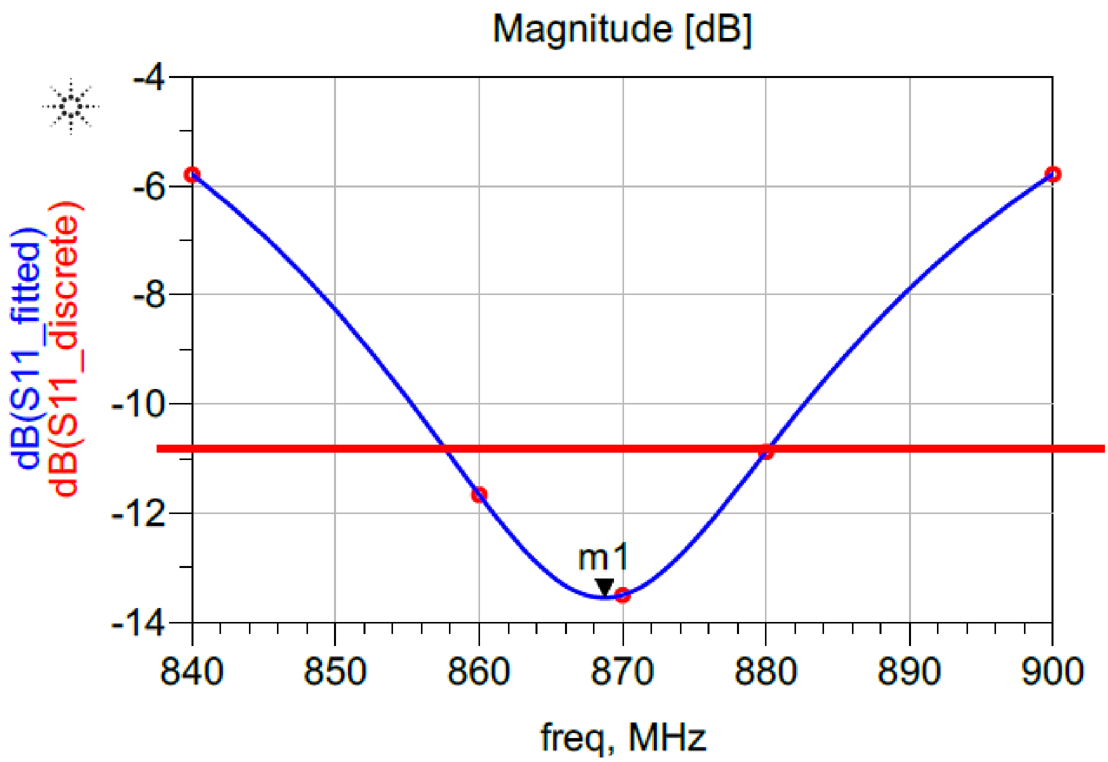


Figure 5.4. S_{11} parameters.

On Figure 5.4 you can see simulated S_{11} parameters of projected antenna. This simulation goes down below -10 dB on right frequency 868 MHz, that means the antenna is correct (fitted). "m1" point is placed on 868 MHz and amount -13.55 dB. Figure 5.5 shows our IFA on Smith chart. Point "m2" is placed on frequency 868 MHz. Momentum microwave simulation in ADS was very satisfy, because as You can see point "m2" is close to center of Smith chart.

Figures 5.6, 5.7, 5.8, 5.9 show antenna Gain, Directivity, Efficiency and Power radiation. Gain is low, because this antenna radiate in almost every direction. Radiation patters shown in figures 5.10 and 5.11. Gain of our antenna is about 0.3 dB, directivity = 2.13 dB, efficiency = 65.65 % and power radiation = 14 mW. From radiation patter is result that is a omnidirectional antenna.

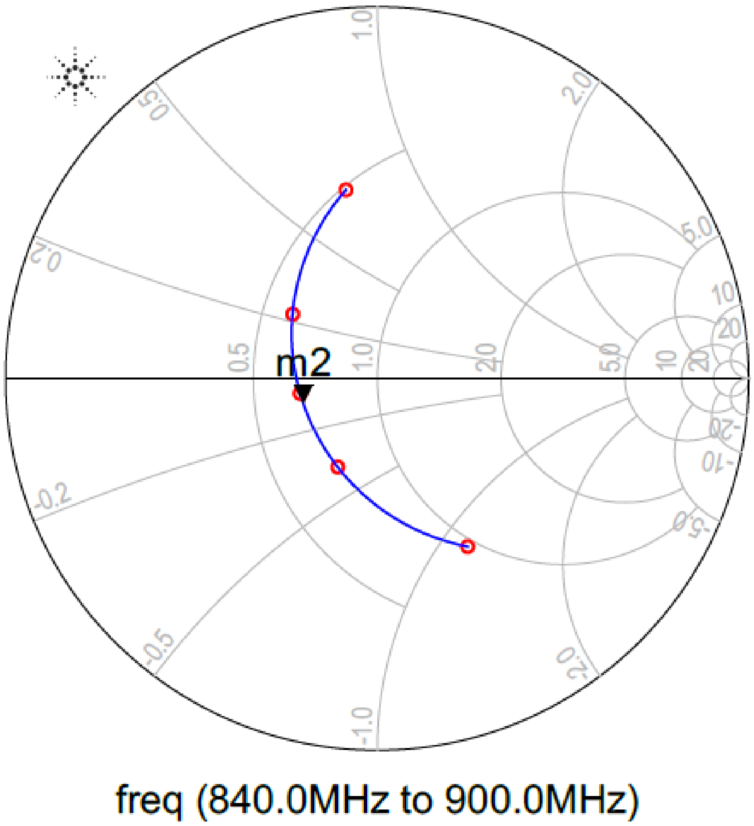


Figure 5.5. Simulated IFA on Smith chart.

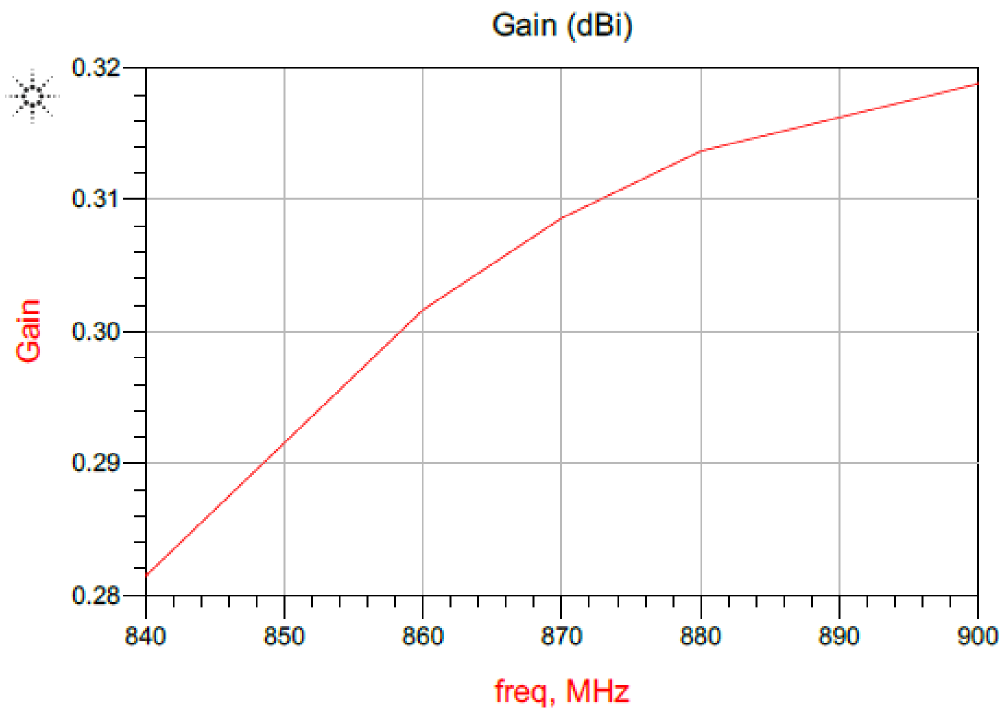


Figure 5.6. Gain.

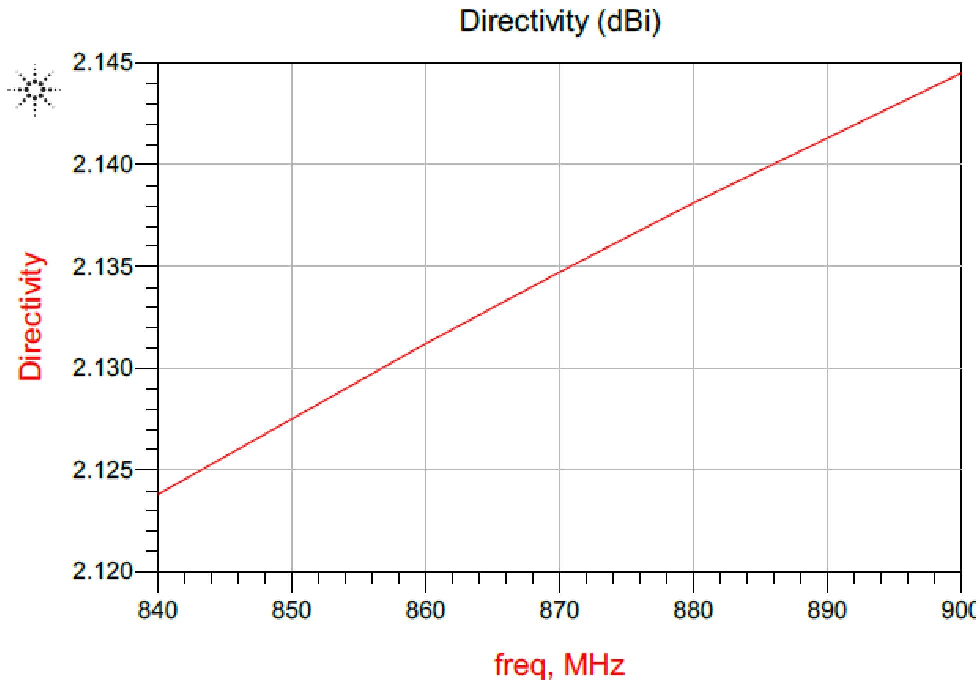


Figure 5.7. Directivity.

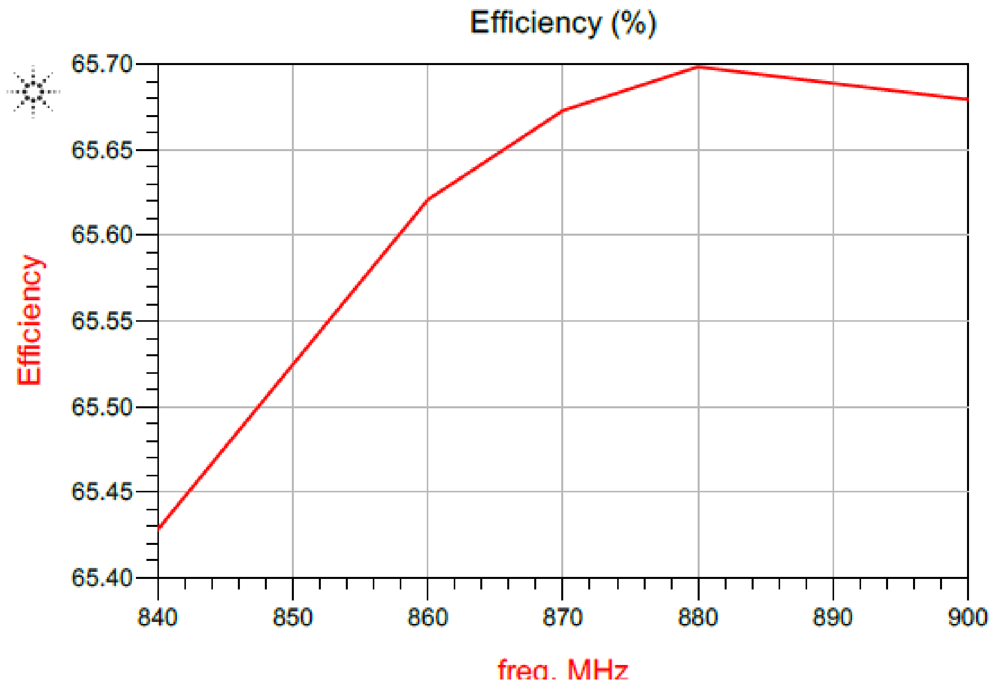


Figure 5.8. Efficiency.

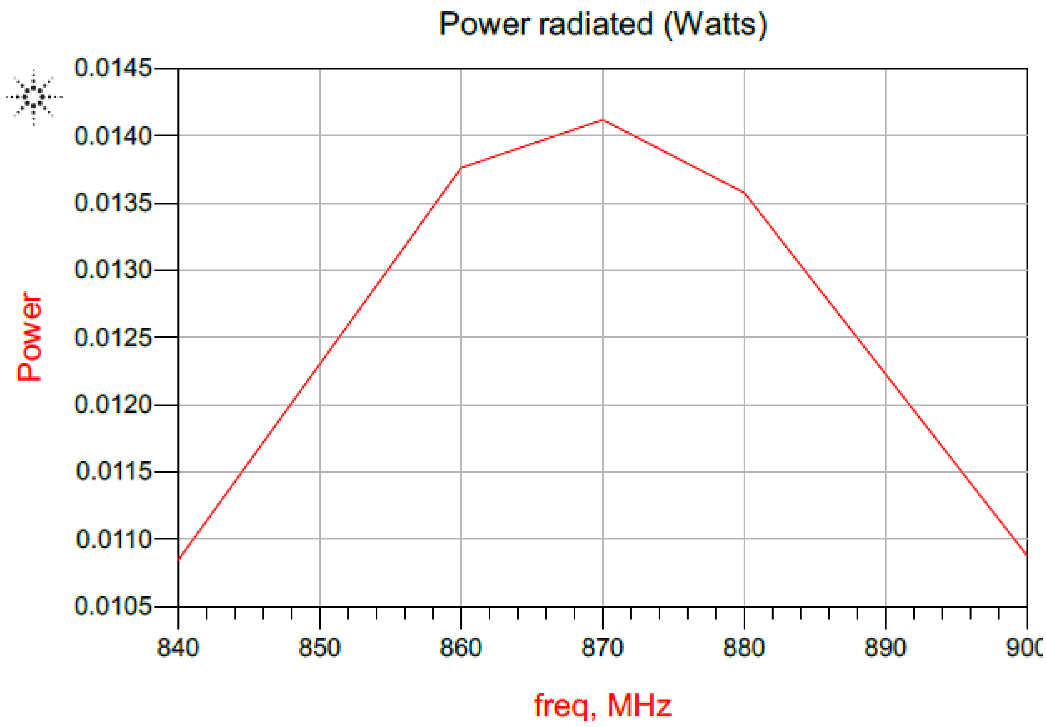


Figure 5.9. Power radiation.

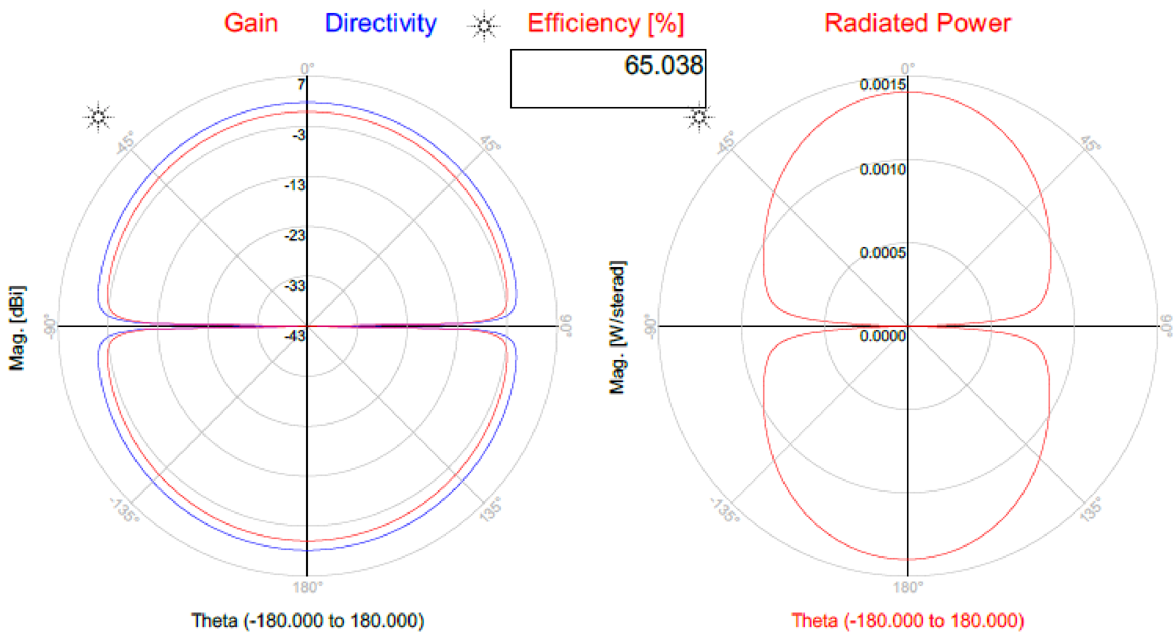


Figure 5.10. Radiation pattern - part 1. $\varphi=0^{O}$

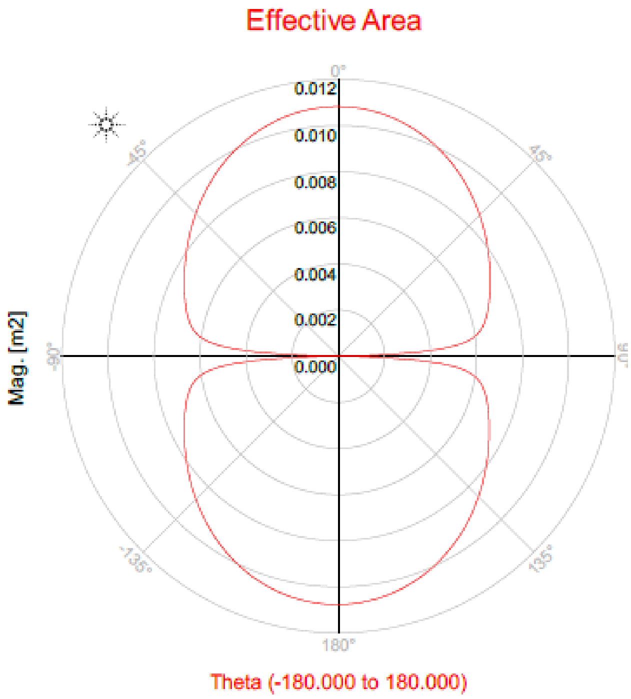


Figure 5.11. Radiation pattern - part 2. $\varphi=0^{O}$

5.3. Measurements.

This chapter talks about real measurements of produced antenna. There is unusual situation, because produced antenna is over 2 times better than simulated. When You look on Figure 5.12 and 5.13 You can see that produced antenna is excellent. Gain is on level about - 30 dB and the smith chart shown in Figure 5.13 told that our frequency 868 MHz is near by the middle of graph. On Figures 5.14 and 5.15 You can see comparing of Momentum simulation results with real antenna. That give us over 60 % of "fair" and "good" result.

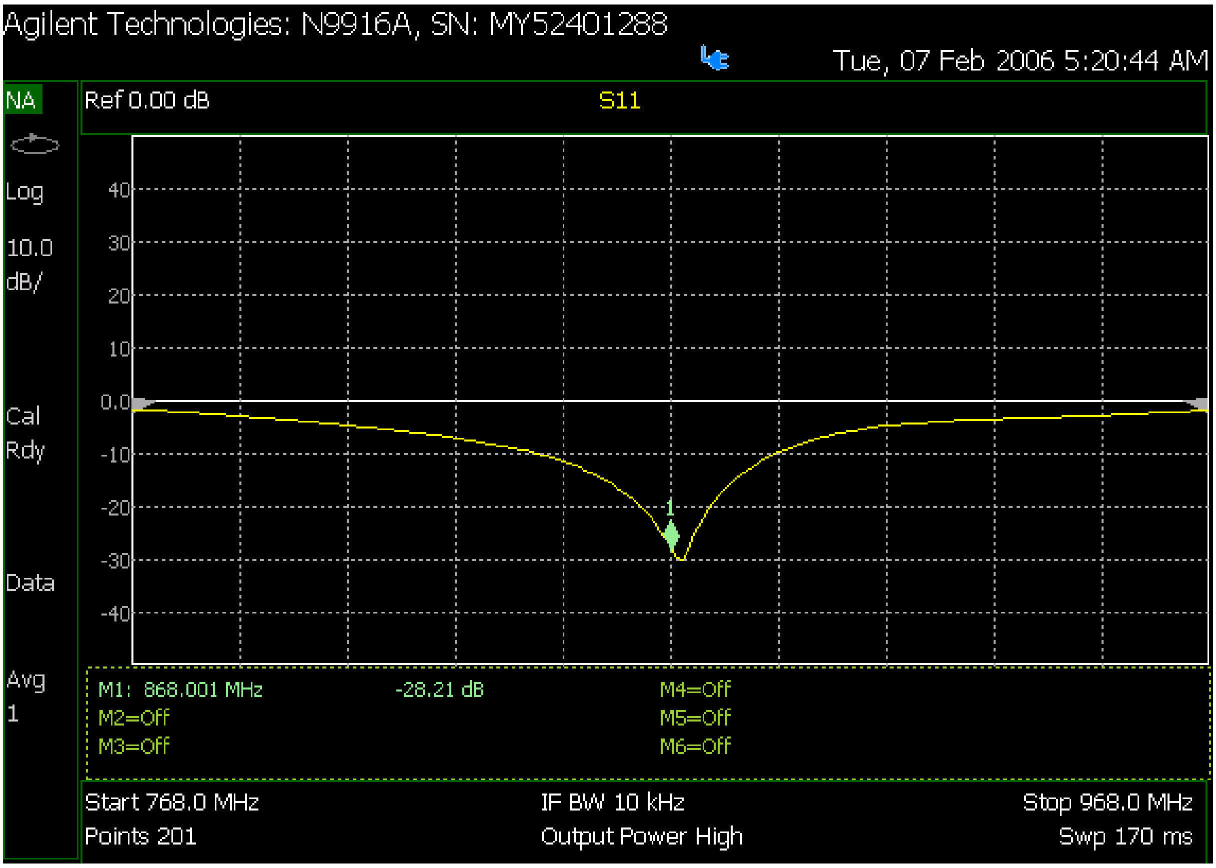


Figure 5.12. S_{11} parameter of produced antenna.

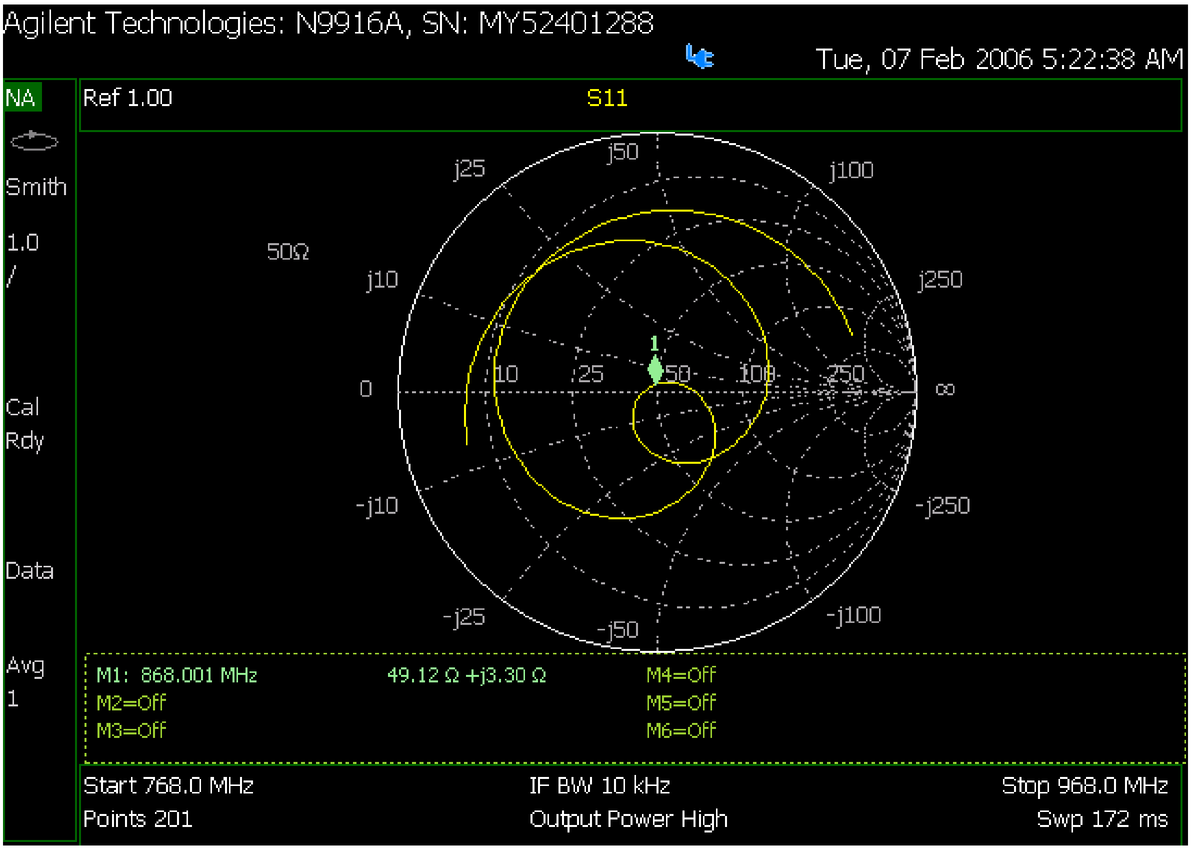


Figure 5.13. Smith chart of produced antenna.

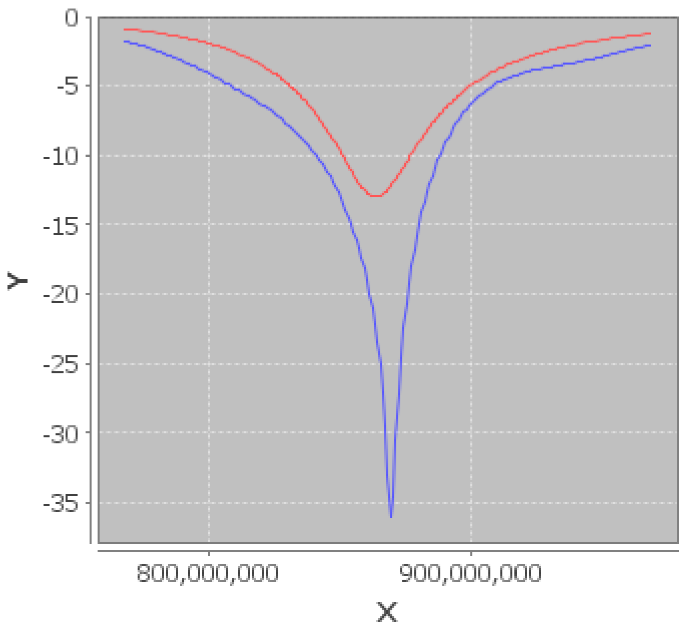


Figure 5.14. Comparison of Momentum Microwave simulation from ADS (red line) and real measure (blue line). Y axis is in dB and X axis is frequency [Hz].

To compare this two data, simulated from ADS and measurement of real IFA, I used FSV algorithm.

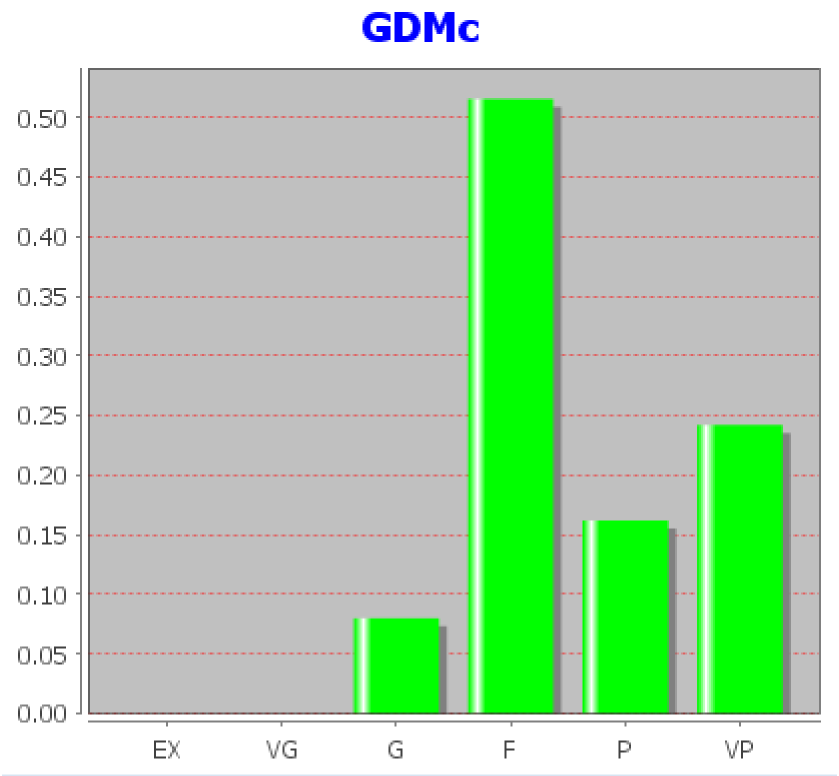


Figure 5.15. GDM from FSV (Momentum Microwave sim and real measurements).

6. Conclusion.

Patch antennas in this time is really popular. Almost every mobile and home electrical device have microstrip antenna, beginning from cell phones, ending on TV's and laptops. The biggest advice is a dimensions of patch antennas. They are very small and We can put them almost everywhere.

To summarise all results, the best tool to simulation antenna is Momentum microwave from ADS. That simulation give the most similar results to produced antenna. To mach frequency and to take the best S_{11} parameters it is necessary to manipulate length of radiation stripe and microstrip close to feed point. Final result are better than an original concept from Texas Instruments, that means in changing prototype we achieve success.

7. References.

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TT-25AL/20AH Conversion Equipments

This article was published by RCA in Broadcast News, Vol. No. 67, January-February, 1952.

FIG. 2. External view of the low band amplifier for channels 2 to 6.

TT-25AL/20AH CONVERSION EQUIPMENTS

HOW TO CONVERT AN OPERATING 5-KW TV STATION ON VHF TO 200 KW (ERP)

by F. E. TALMAGE
BROADCAST TRANSMITTER ENGINEERING

The TT-25AL and the TT-20AH conversion equipments are high power amplifiers for use with 5 kilowatt television transmitters. The TT-25AL operates on channels 2 through 6 and will provide up to 25 KW peak visual power and 12.5 KW aural power. The TT-20AH operates on channels 7 through 13 and will supply up to 20 KW peak visual power and 10 KW aural power. These equipments are designed primarily to operate with the RCA TT-5A television transmitter but can also be furnished for use with any other 5 KW television transmitter meeting the FCC and RTMA specifications.

In the light of the effective radiated power increases which the FCC has granted recently to operating TV stations in the

Using the TT-25AL/20AH Conversion Units with a 5-KW Transmitter as a driver, it is possible for a station to multiply its transmitter power 4 or 5 times, depending upon whether the channel in use is low band or high band. Thus, a transmitter with a 20-KW output, used in conjunction with a 6-bay antenna and an average length of line would give an effective radiated power of at least 100 KW. With a 12-bay antenna, the ERP would become at least 200 KW.

The advantages of higher power are obvious. The station gets increased coverage

changed. The video and audio signals are fed to the driver and the modulation occurs in this unit. The RF output from the visual driver is fed to a class "B" linear amplifier. The aural amplifier is similar to the visual amplifier except that it may be operated class "C" since the sound carrier is frequency modulated.

Construction

The power and control equipment for the amplifiers are housed in four cabinets which match the cabinet of the RCA TT-5A. These cabinets may be placed either in line with the TT-5A or at right angles. Several suggested floor plans are shown on the preceding pages. Since the two power supply cabinets do not contain

recently to operating TV stations in the VHF band, the RCA Transmitter Power-Conversion Equipment has assumed new importance to the industry. For the TV station on-the-air which began life on a small scale, the opportunity to raise its effective radiated power is afforded through a conversion job, rather than a complete, new installation.

vious. The station gets increased coverage with its signal, plus better signal to noise ratio in the picture. More effective use of indoor antennas is possible in the reception area, and there is less receiver oscillation interference.

Fig. 1 is a block diagram of the TT-25AL/TT-20AH equipment. The internal circuits of the 5 KW driver are not

any operating controls or meters, they can be mounted either with the other cabinets or in the rear as shown in the second floor plan.

The RF circuits are housed in two cylindrical cabinets illustrated in Fig. 2. The units for the visual and for the aural amplifier are mechanically almost identical.

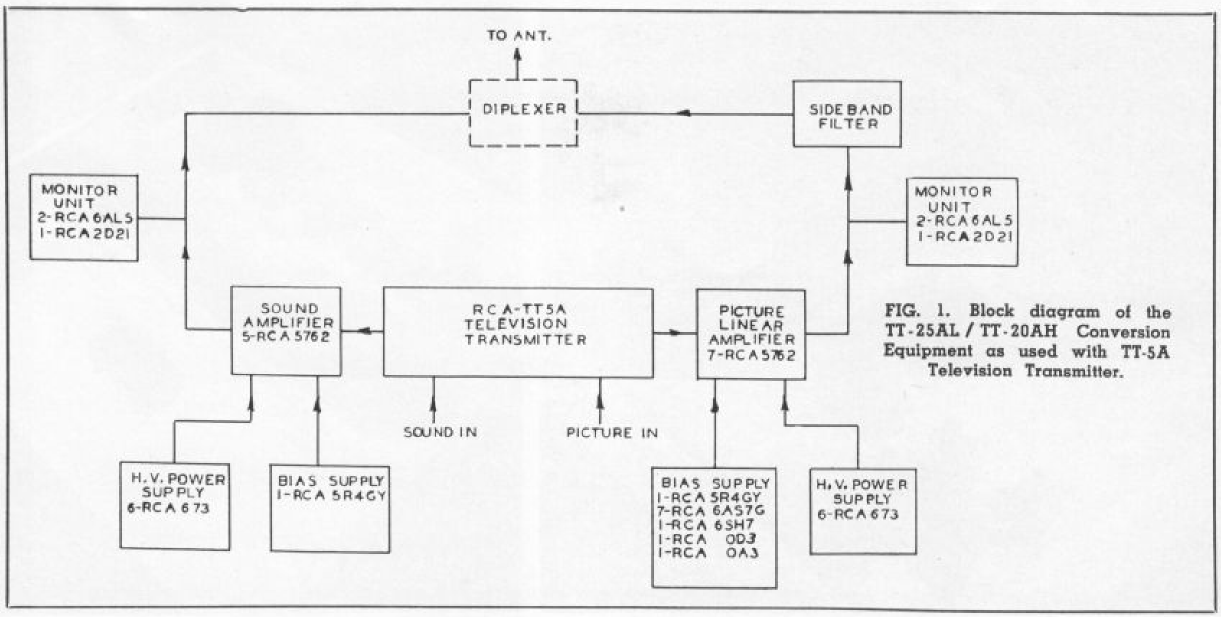
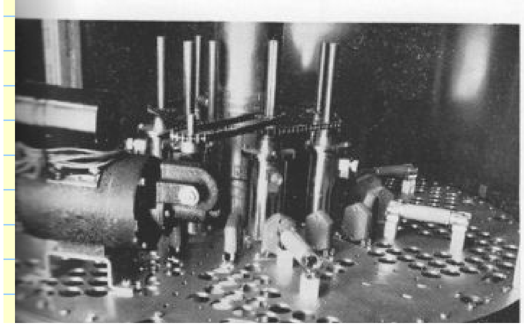


FIG. 1. Block diagram of the TT-25AL / TT-20AH Conversion Equipment as used with TT-5A Television Transmitter.

The lower rectangular section of the amplifier unit houses the blower, filament transformers, meters and tuning controls while the upper cylindrical section contains the tubes and RF circuits. Air for cooling the tubes is drawn in through two filters on the sides of the bottom section and is expelled out the top of the unit. Access to the tubes is obtained through four hinged doors near the top of the unit. All other parts are easily accessible for servicing by removing the top dust cover, the side plates or the filters. The reflectometer and monitor circuits are contained in a separate unit which may be inserted in any convenient place in the output line.



Circuit Description

The visual RF amplifiers for both the low-band and the high-band equipments each employ seven RCA-5762 air cooled tubes operating in parallel in a grounded grid circuit. The tubes are placed in a circle as shown in Fig. 3. The aural amplifier also contains seven RCA-5762 tubes in an almost identical circuit, however, the filaments of two of the seven tubes may be turned off if desired, leaving only five operating tubes. The general appearance of the low and high band units are similar but the internal circuits necessarily differ in several important respects. Both the low and the high band units will be described separately below in more detail.

Low-band Amplifier: The operation of the low-band unit can best be understood by referring both to the simplified equivalent circuit Fig. 5 and the cut-away view of the amplifier shown in Fig. 4. The plate tank circuit is tuned by (L-10). As can be seen in the cut-away view, this inductance is a co-axial tank formed by the outer shell, and an inner cylinder, and varied by a shorting bar located below the tubes. The shorting bar is motor driven and controlled

proximately one quarter wave from C-40. This secondary circuit is tuned by sliding capacitor (C-10) along the line. The inductance L-30 shown in the equivalent circuit is actually the first quarter wave of the output transmission line. By a suitable selection of the value of capacitor (C-10) and proper adjustment of the coupling capacitor (C-40) a broadband flat-topped circuit can be obtained as illustrated in Fig. 6. The optimum circuit has been found to be 8½ to 10 megacycles wide between half power points and almost flat over the six megacycle channel.

The input or cathode circuit is also essentially a co-axial tank circuit tuned by a shorting bar shown near the center of Fig. 4 just above the tube level. In the equivalent circuit this is shown as a variable inductance (L-40). Because of the high input capacity of seven tubes in parallel this tank is actually much less than a quarter of a wavelength long. A large part of the inductance is formed in the tube and by the tube leads. The input line is fed through the center of the cathode tank and is connected in series with the input circuit at a low impedance point. In order to

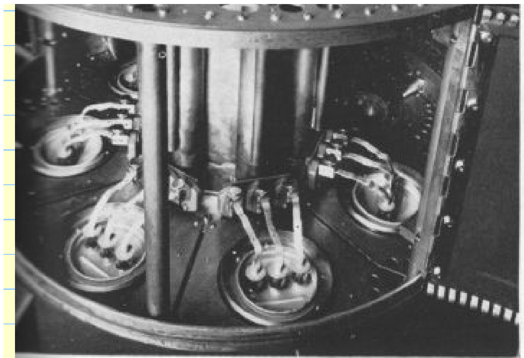


FIG. 3. Closeup showing the cluster of seven air-cooled 5762 triodes used in the 20 kw amplifier equipment.

from the front panel. The output transmission line is brought up through the center of the tank and coupled to the plate circuit through a variable capacitor (C-40). This capacitor is also motor driven and controlled from the front panel. What is equivalent to a second tuned circuit is formed by inserting a shunt capacitor (C-10) in the output transmission line ap-

match this impedance to the 72 ohm line from the driver two quarter-wave transformer sections T9 and T10 are employed. In the cut-away view these are shown built into the 3⅛" input line by using the proper size center conductors for the quarter-wave sections.

To allow for variation in tube input capacity and for variation in feed-through power, a means for making some adjustment to the input coupling must be provided. In the low band amplifier this is ac-

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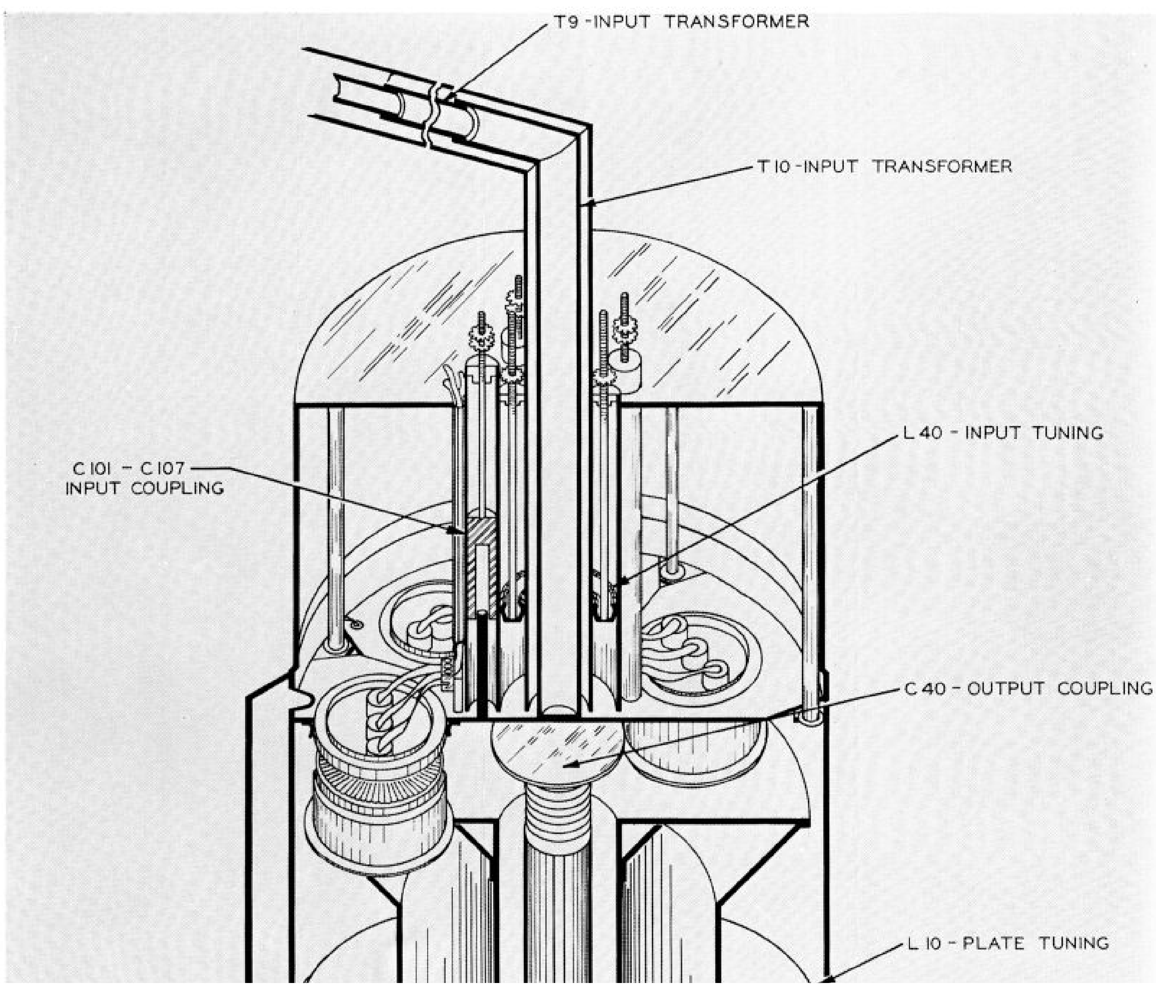
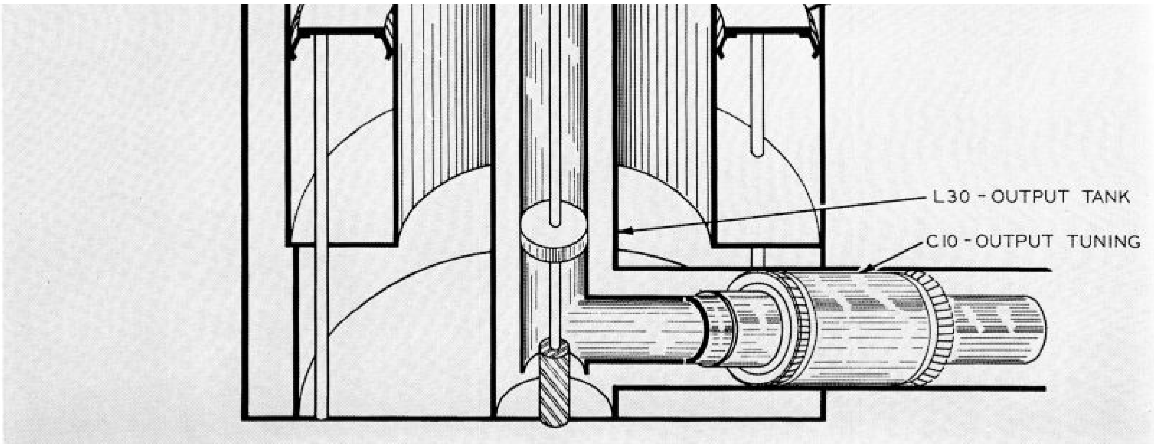
complished by adding in shunt capacitors C-101—C-107. As can be seen in Fig. 4 these capacitors take the form of seven co-axial capacitors. To vary the capacity a mycalex cylinder which has a dielectric constant of approximately 6 is inserted between the center and outer tubes. These seven mycalex cylinders are mechanically ganged together and driven by a tuning motor. Since the tube leads form a portion of the tank inductance these capacitors are not actually in parallel with the tube input but are part way down the tank circuit where it has been found that they serve as a coupling adjustment and have little effect on the resonant frequency of the circuit.

High Band Amplifier: A cut-away view of the high band amplifier is shown in Fig. 8 and the simplified equivalent circuit is shown in Fig. 9. The general appearance of this unit is similar to the low band unit, but the circuit actually differs in several important details. Because the operating frequency is much higher, it would be impractical to use a simple quarter wave concentric line tank similar to that used in the low band amplifier since there would be little or no tank circuit left outside of the tubes themselves. To overcome this, two

FIG. 4. Cut-away view showing R-F circuits of the TT-25AL Amplifier.





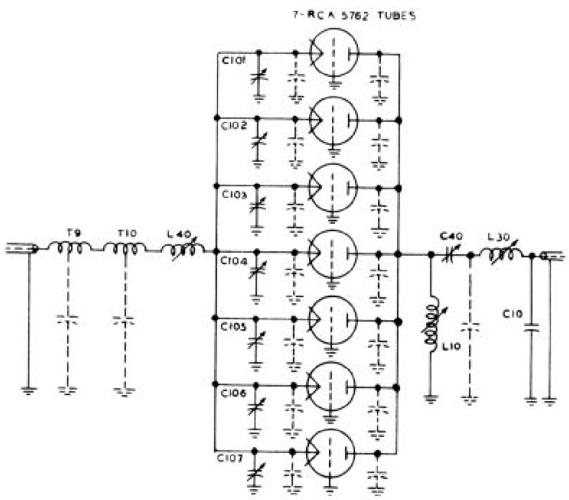


FIG. 5. Simplified equivalent circuit of the TT-25AL (low band amplifier).

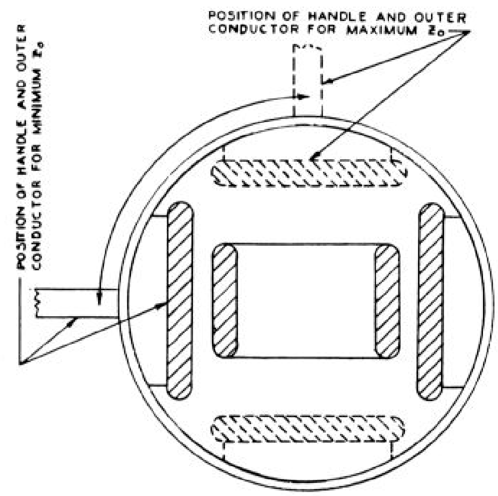


FIG. 7. Cross-section view of variable Z_o transformer used in TT-20AH.

co-axial tank circuits are employed. One of these tanks is inside the other as shown in Fig. 8. These function as inductances in parallel and thus raise the effective resonant frequency. In the equivalent circuit these inductances are (L-10) and (L-20). The output is coupled to the inner of these plate tank circuits across a shunt inductance L-60. To preserve the circuit symmetry this inductance is actually made up of seven small adjustable shorted transmission lines connected in parallel and located on a circle just inside the inner plate tank. Like the low band unit, the secondary or output circuit is formed by inserting a shunt capacitor C-10 in the output transmission line and is tuned by sliding this capacitor along the line. Because the two circuits are coupled at a low impedance point this capacitor is located approximately ¼ wave length along the line. This provide for an input coupling adjustment one of the transformers (T-9) is constructed so as to have a variable characteristic impedance as the outer shell is rotated through 90°. A cross sectional view of this transformer is shown in Fig. 7 (above).

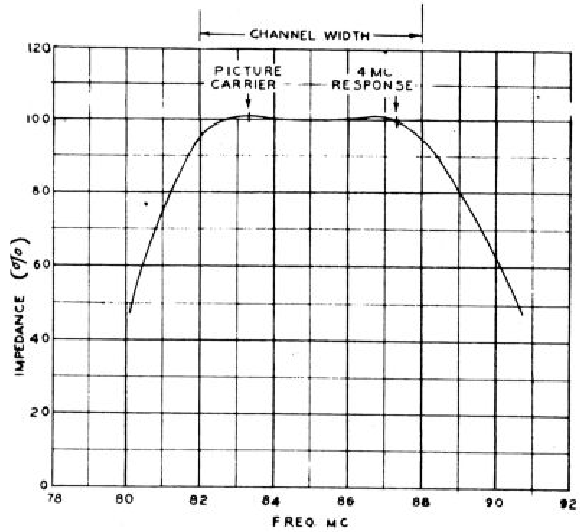
Power and Control Equipment: The control equipment is of conventional design. An instantaneous trip relay is connected in the cathode return circuit of each of the seven power amplifier tubes. In addition, a total d-c current relay is provided and a-c relays are inserted in the primary leads of the high voltage plate transformer. The overload system has an automatic reset feature. After an overload occurs the plate voltage will be removed momentarily then automatically returned twice. If the overload persists for the third time the plate voltage will remain off. All circuits such as the filament bus, the blower and the bias supply are protected by breakers with built-in overload trip coils. The control equipment for the aural transmitter is identical to that for the visual transmitter and the two are arranged so that the two carriers may be turned on and off independently.

Except for the bias supply and slight differences in the high voltage filter, the power equipment for the aural and visual equipments are identical. The high voltage rectifiers for each employs six RCA-673

mately ½ wave length along the line. This secondary circuit, coupled to the plate circuit by means of a mutual reactance L-60, forms the necessary elements of an over-coupled broadband circuit whose response is equivalent to that shown in Fig. 6 for channel 6.

The cathode circuit, like the plate circuit, cannot be made a conventional quarter-wave tank because the first low impedance point will occur on the tube straps. To compensate for this extra inductance of the straps, the seven co-axial capacitors C-101—C-107 are connected in series with the tube leads instead of in shunt as was the case in the low band amplifier. These capacitors are variable and when mechanically ganged together serve as the input tuning control. This cathode circuit is matched to the 72 ohm input by two quarter-wave transformer sections in series. To

FIG. 6. Curve showing typical response of TT-25AL output circuit, channel 6.



mercury vapor rectifier tubes in a three-phase full wave circuit with a balance coil. The bias supply for the visual amplifier is well regulated, its output voltage remaining constant for large changes in grid current. The bias for the aural amplifier is essentially obtained from grid leaks with just enough fixed bias to protect the tubes when there is no drive.

Installation

The layouts shown in the floor plans on the pages preceding this article are only three of many possible arrangements. In all three views the amplifiers are shown in the rear of the driver. Actually they can be located at the ends or at right angles to the TT-5A. This feature should be of particular interest to those stations which already have their 5 KW driver and are limited in available space to add an amplifier. The important thing to keep in mind is that the length of transmission line between the driver and the amplifier should be kept as short as possible. Distances between the output of the driver and the center line of the amplifier of 15 feet or less should be satisfactory. If the distance is much greater than this it will be difficult to obtain the required bandwidth. To understand why the line cannot be too long it should be remembered that the amplifier input circuit is essentially a single tuned circuit and can terminate the line exactly at only one frequency. To provide for a line of indefinite length, it would have to have a standing wave ratio of better than 1.1 to 1 over the six megacycle channel. This would mean that the bandwidth of the terminating cir-

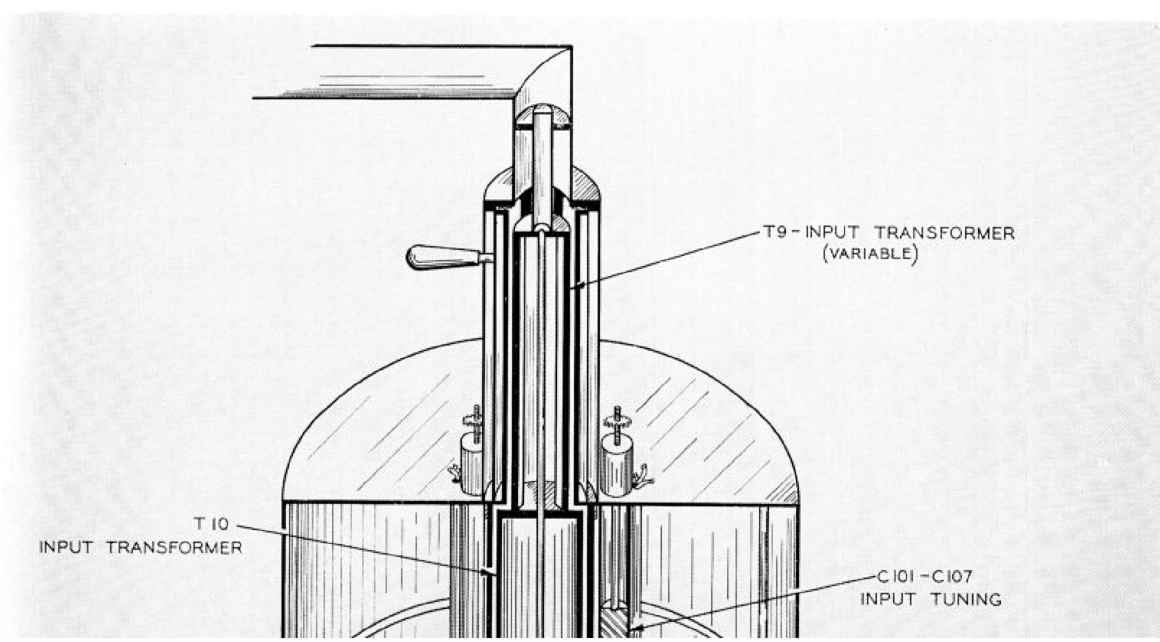
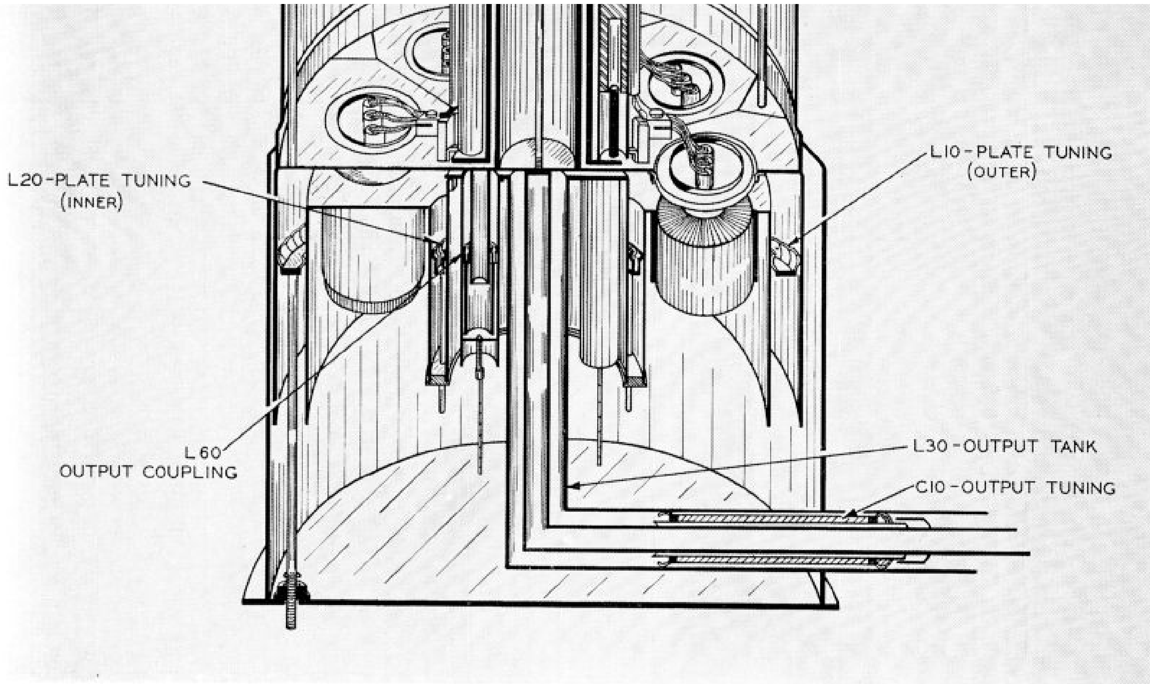


FIG. 8. Cut-away view



...away view showing R-F circuits of the TT-20AH high-band amplifier.

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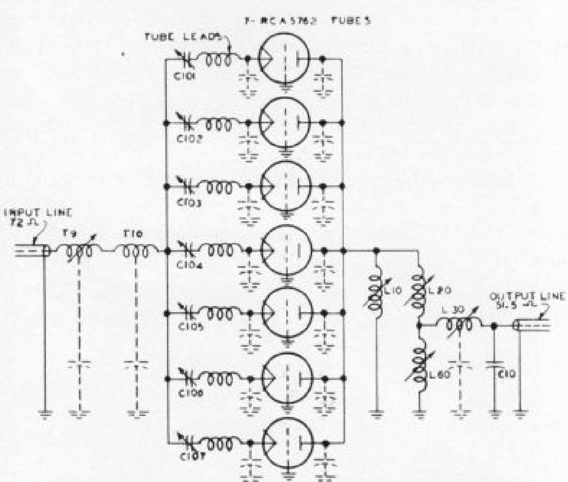
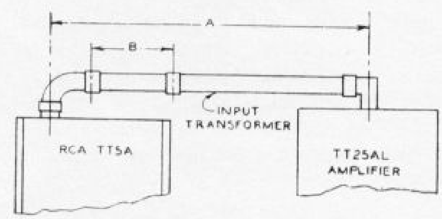


FIG. 9. Equivalent circuit of the TT-20AH Amplifier for channels 7 to 13.



CHANNEL NO.	A (INCHES)	B (INCHES)	$\frac{1}{2}$ WAVELENGTH
2	121	25	$103\frac{5}{8}$
3	101	5	$93\frac{3}{4}$
4	175	77	$85\frac{5}{8}$
5	141	45	$74\frac{3}{4}$
6	125	29	$69\frac{3}{8}$

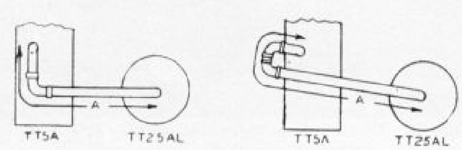
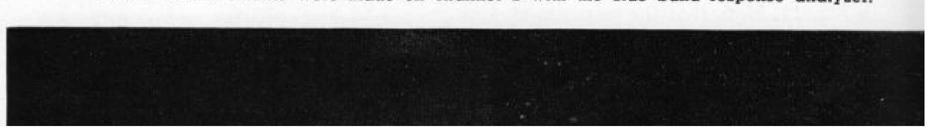


FIG. 10. Table and sketches showing length of line between driver and 25 kw amplifier and several ways of running the line to obtain the correct length.

cuit be 60 megacycles between half power points. On channel 2 this is equivalent to having a Q of 1 which is obviously an impractical condition. It is necessary, therefore, that the input circuit of the amplifier must be a part of the driver output circuit. On the low channels it is not only impor-

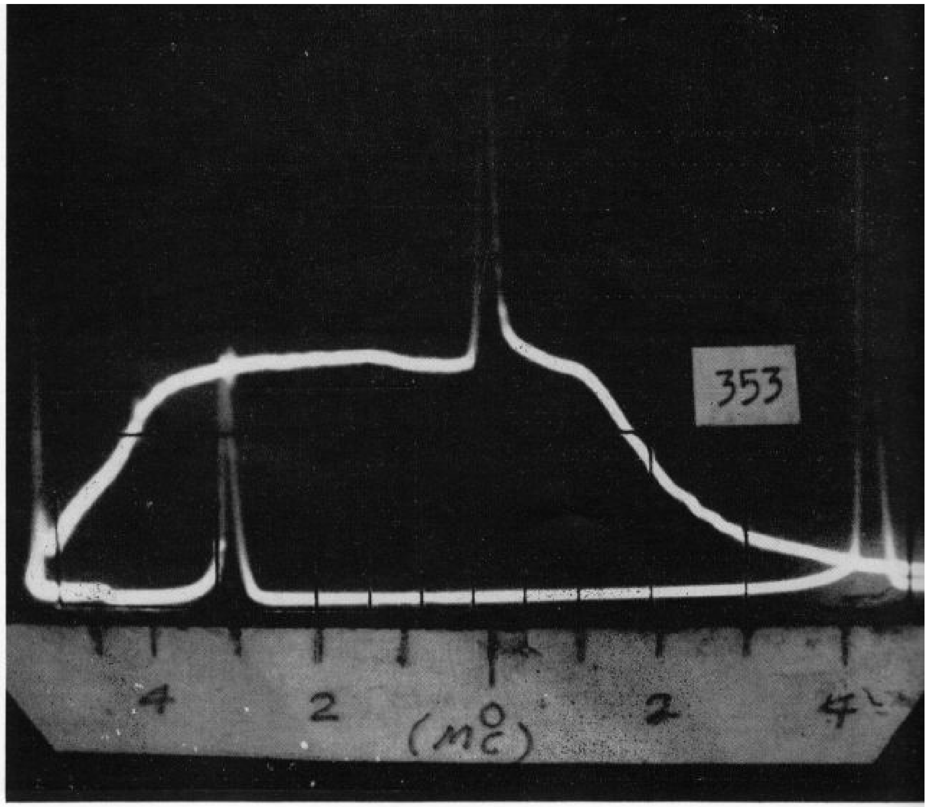
FIG. 11. Overall frequency response of the TT-25AL Transmitter including the TT-5A Driver. Measurements were made on channel 2 with the side band response analyzer.



tant that the length of line be kept short but the effective length of line should be in approximate multiples of ½ wavelength. Fig. 10 gives a table of the recommended length of line for the low band channels. This line does not necessarily have to be straight but can have a right angle bend or a 180° fold as shown in the two bottom views in Fig. 10.

Performance

A summary of the performance specifications is shown on the next page. When the TT-25AL or the TT-20AH amplifier is used with the TT-5A the overall performance will meet all the RTMA and FCC requirements. The overall linearity curve is shown in Fig. 12 and the linearity curve for the input signal is shown in Fig. 13. From these two curves we have plotted the linearity of the amplifier alone. This is shown in Fig. 14. It will be noted that the amplifier introduces almost negligible amplitude distortion except in the sync region where it can be easily compensated for by the sync stretcher in the TT-5A.



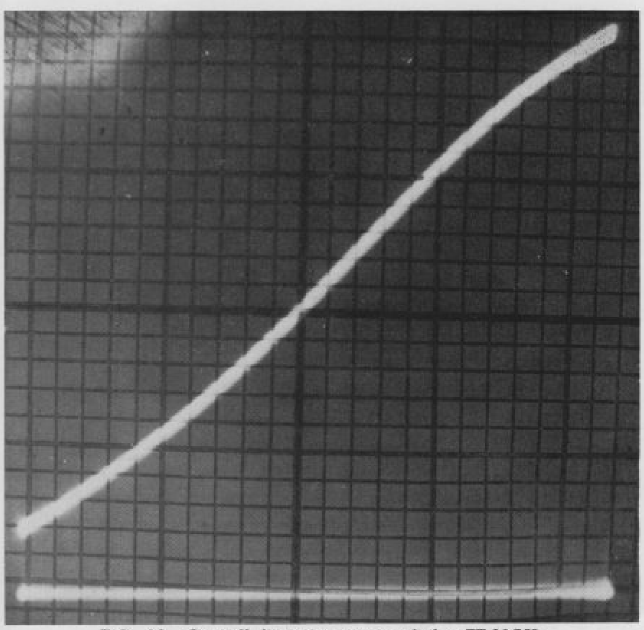


FIG. 12. Overall linearity curve of the TT-20AH including the TT-5A driver.

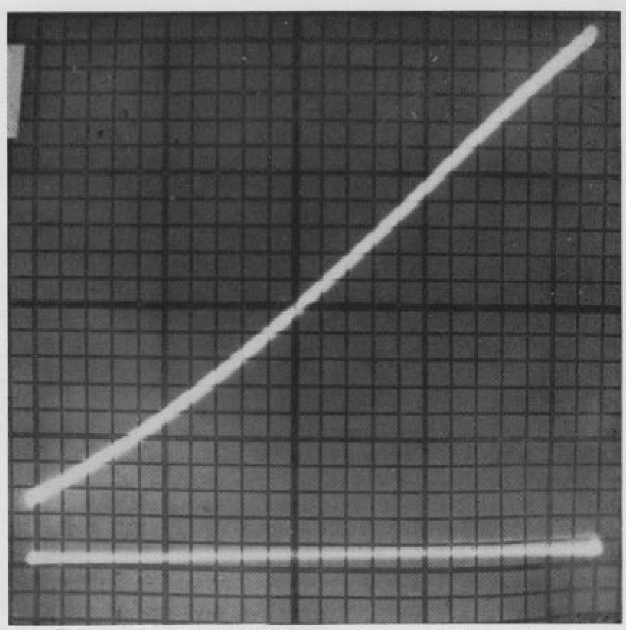


FIG. 13. Linearity curve of the TT-5A driver made under the same conditions as those of Fig. 12.

A typical overall frequency response curve without a sideband filter as viewed on the sideband response analyzer is shown in Fig. 11. Note that the response at 4 mc

Visual............***2 db at 0.5 mc
2 db at 1.25 mc
2 db at 2.0 mc
2 db at 3.0 mc

Ambient Temperature:
Minimum ....+10° C
Maximum ....+45° C

in Fig. 11. Note that the response at 4 mc. is considerably better than the 4 db limit proposed by the RTMA standard.

Performance Specifications*

Type of Emission:

Aural A3

Visual A5

Frequency Range:

TT-25AL ....Channels 2-6

TT-20AH ....Channels 7-13

Power Output:

TT-25AL

Aural ....12.5 kw

Visual....25 kw from sideband filter

TT-20AH

Aural ....10 kw

Visual.....20 kw from sideband filter

R-f Output Impedance........51.5 ohms

Frequency Response:

Aural..............**Uniform ±1 db 30 to 15000 cy.

3 db at 4.0 mc

Power Line Requirements:

Voltage 208/230

Phase 3

Frequency ....60 cycles

Instantaneous Regulation ....±3%

Slow Time Drift..............±5%

Power Consumption (approx.) 60 kw (with black picture) (Conversion Equipment only)

Power Factor (approx.)..........0.90

Exhaust air recommended for cooling, aural and visual amplifiers only, each 2000 cfm.†

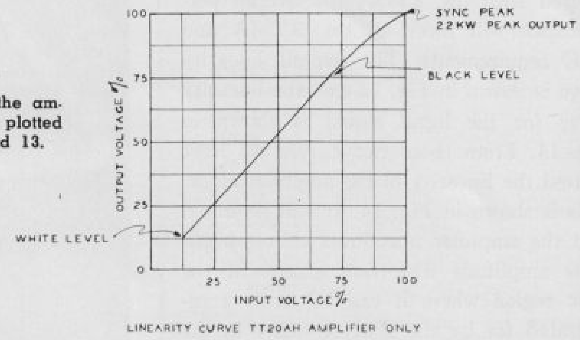
* The overall performance of a TV Transmitter using a TT-25AL or TT-20AH Amplifier is necessarily dependent upon and governed by the performance of those portions of the transmitter preceding the amplifier.

** For pre-emphasized response, the pre-emphasis filter (MI-4926-A) may be inserted in the 600 ohm audio input at the most effective point.

*** Maximum variation with respect to the idealized rectified vestigial sideband response. These are overall limits when the amplifier is used with the TT-5A Television Transmitter.

† Air ducts from the top of each amplifier are recommended. The above figure is based on a duct with approximately four square feet cross section. Operation without ducts requires considerably more air movement.

FIG. 14. Linearity curve of the amplifier only. The curve was plotted by comparing Figs. 12 and 13.



4/12/10

John's Home Page

W0BTU Broadband Preamps
for Low-Noise Receiving Antennas

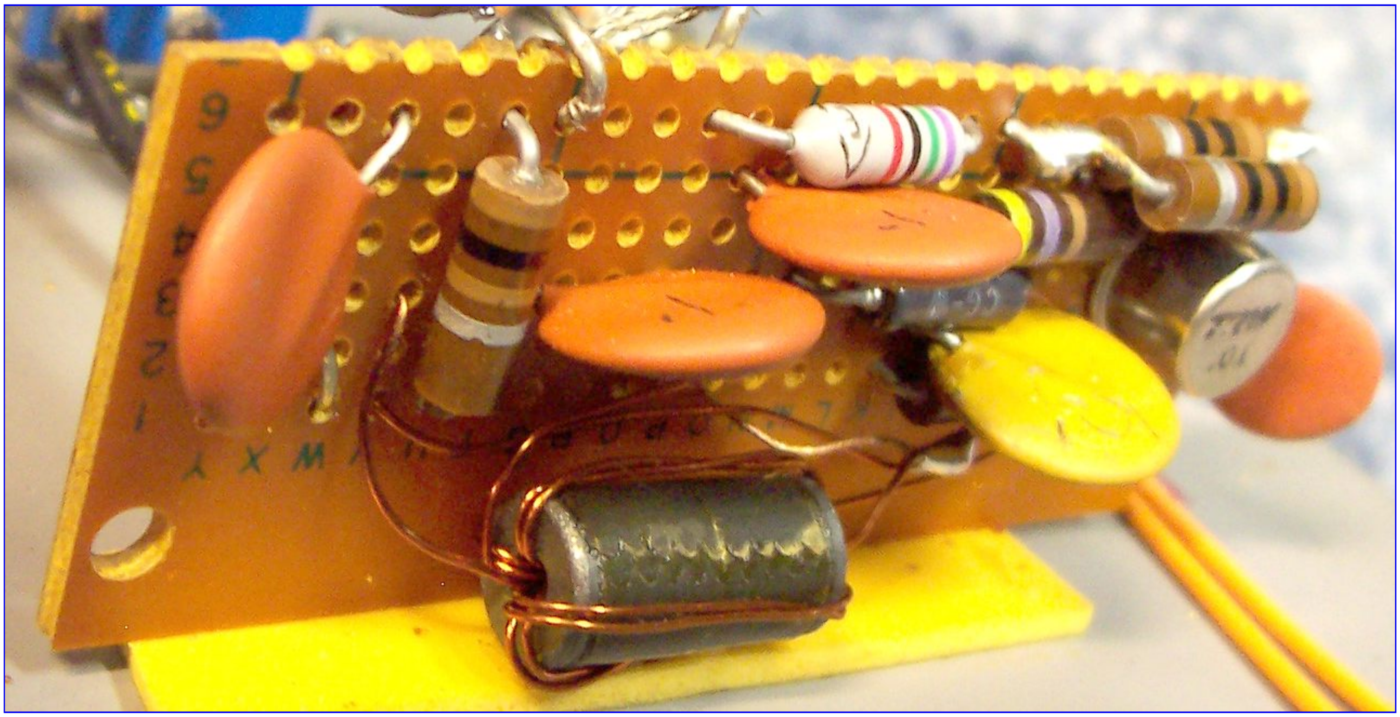
Covers approx. 100 kHz to 30 MHz

- Based on a design in *Solid State Design For the Radio Amateur*, © 1977 ARRL - Pages 97, 98, 122, 123. Uses a single bipolar NPN transistor. Presently has an emitter resistor modification suggested by W7IUV, which improves the strong-signal handling capability at the expense of a slightly increased noise figure. Noise figure is usually of secondary importance, especially when the preamp is mounted close to an elevated Beverage rather than next to your radio at the end of a long run of lossy coax. (Don't ask me how I know that. :-)

- I sometimes use this homebrew preamp to boost weak signals from my Beverage receiving antennas.

Broadband preamp using bipolar transistor
Original amplifier - still in use. Modifications (one resistor and a heat sink on the transistor) have been made since this photo was taken. See below.

Transformer uses two Amidon FB-73-801 ferrite beads bifilar wound with # 24 or #26 enameled wire



UPDATED The TRW LT1001A is no longer available; it was given to me years ago. I recently found a letter in my files dated 1994 where Motorola said that **the replacement for the LT1001A was the MRF5812.** That's why I used the MRF5812 in the 2 other preamps below.
The 2N5109 and some similar transistors will also work.

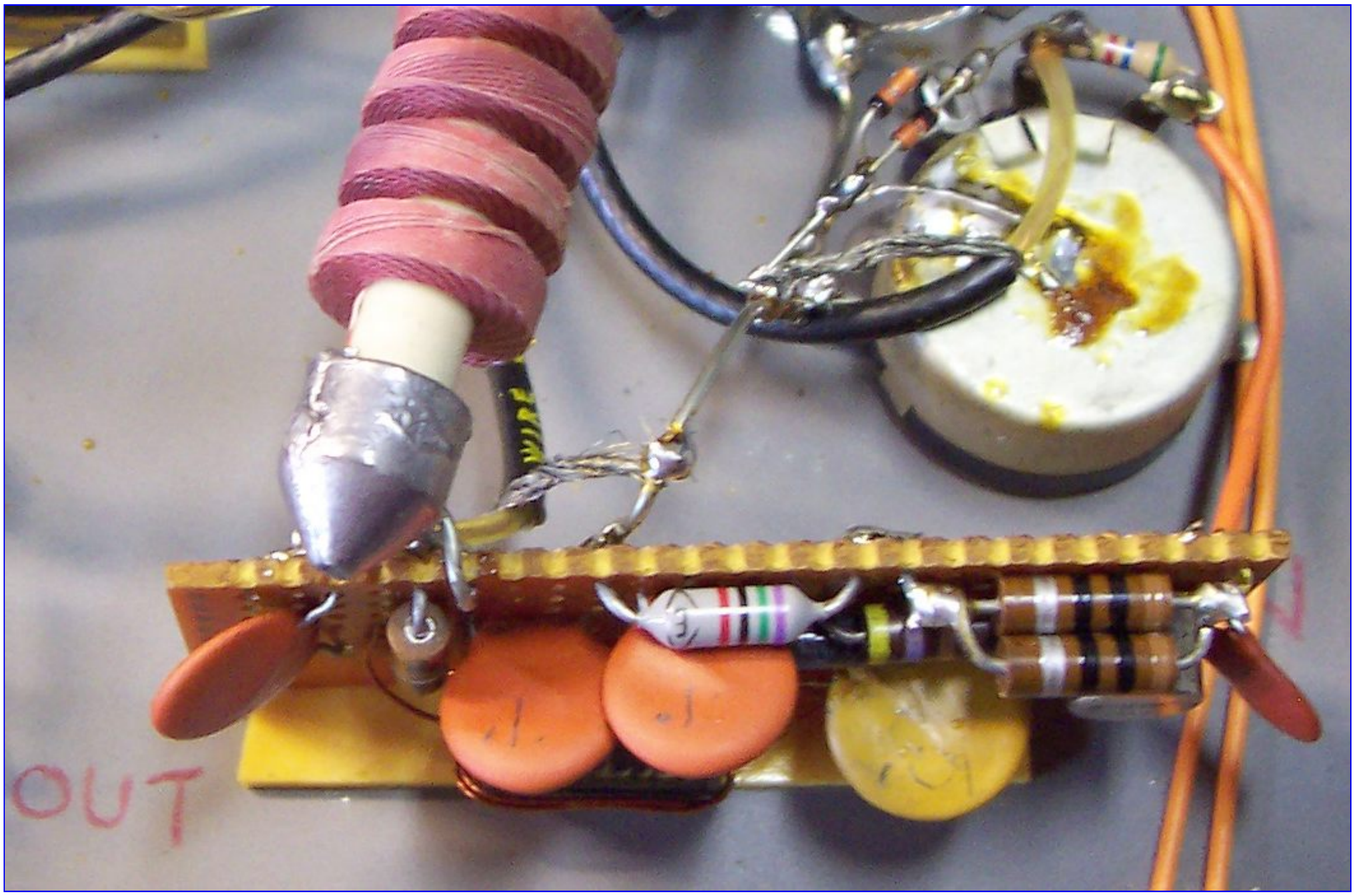
+12 volt DC feed through 2.5 mH RF choke - early design

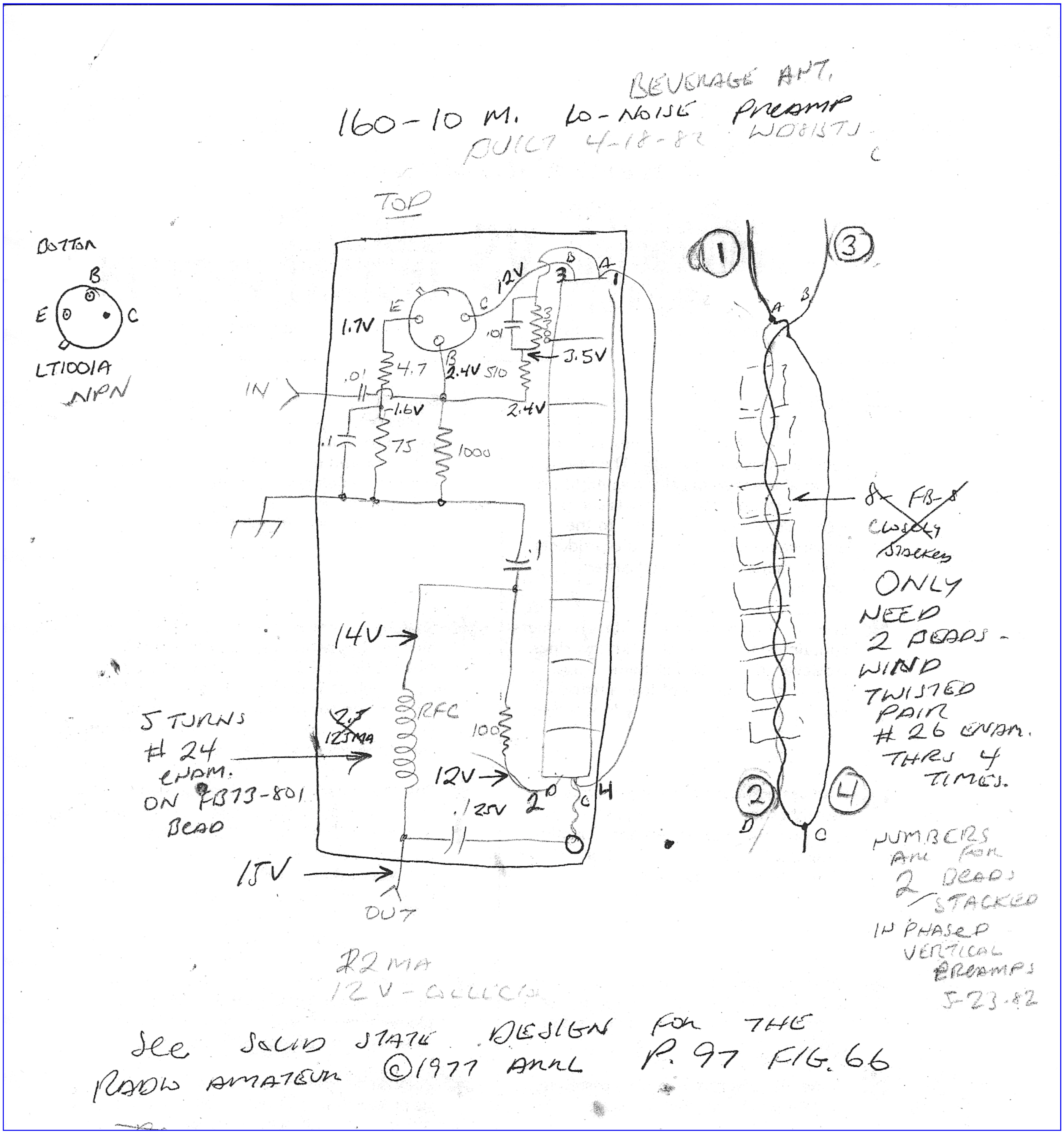
Subsequent RF chokes are made using ~5 turns of enameled wire through single FB-73-801 bead

Two back-to-back 1N914/1N4148 diodes from preamp input to ground also shown. Since this photo was taken, there are now four diodes, two in series in each direction.

There is now a small incandescent lamp in series with the input to prevent damage from nearby transmitting antennas in proximity to the receive antennas.

The pot shown is to reduce the input signal so that I can match the signal levels while comparing different antennas. It's also in series with the input. Approx. 2000 ohms. I use it to reduce the preamp gain so that the signals from the RX antennas are similar in strength to the signals from the TX antenna.


OUT



- Based on a design in *Solid State Design For the Radio Amateur*, © 1977 ARRL - Pages 97, 98, 122, 123

- The RF choke shown in the schematic can be eliminated. It was for locating the preamp remotely near the receive antenna (not usually necessary) and feeding 12 VDC through the coax to power the preamp with a bias-tee arrangement (two broadband RF chokes and two .1 uF disc ceramics).

- Since I created this page, this preamp now has the W7IUV emitter resistor modification which further improves the 3rd order intercept and compression points. W7IUV gives the following performance specifications on his site:

"P1dB (1 dB output compression power) should be greater than +21 dBm. Usually runs about +24 to +27 depending on parts used.

"OIP3 (output third order intercept point) should be +41 dBm or greater. I've seen +44, which is as high as I can accurately measure with my test setup."

Somewhere, he implied that the noise figure is about 6 dB. Likely, the NF is lower without his emitter resistor mod; however, the IM3 is not as good.

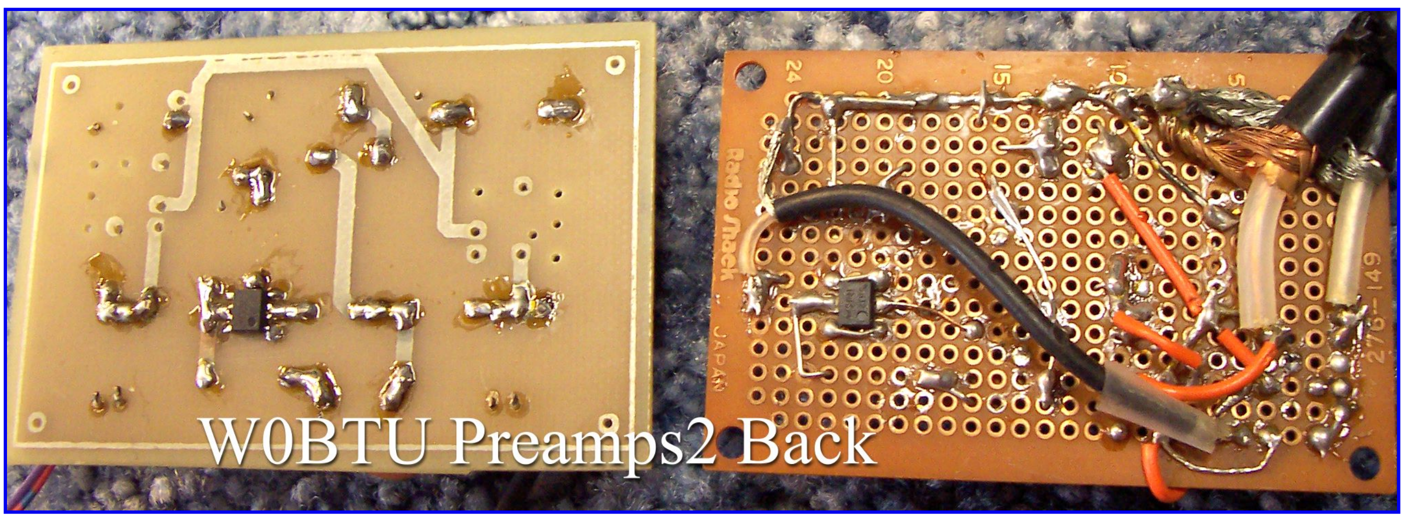
The increased current required a heat sink on the transistor, not shown here.

- There are advantages to using a bipolar transistor over an FET or JFET. See the above-referenced ARRL publication for more information.
- I have only ever used a TRW LT1001A in the original amplifier at the top of this page. It has slightly better specs than the 2N5109. The LT1001A (now unobtanium) was offered for use in CATV applications. **The preamps below use the surface-mount (SO-8) MRF5812.**

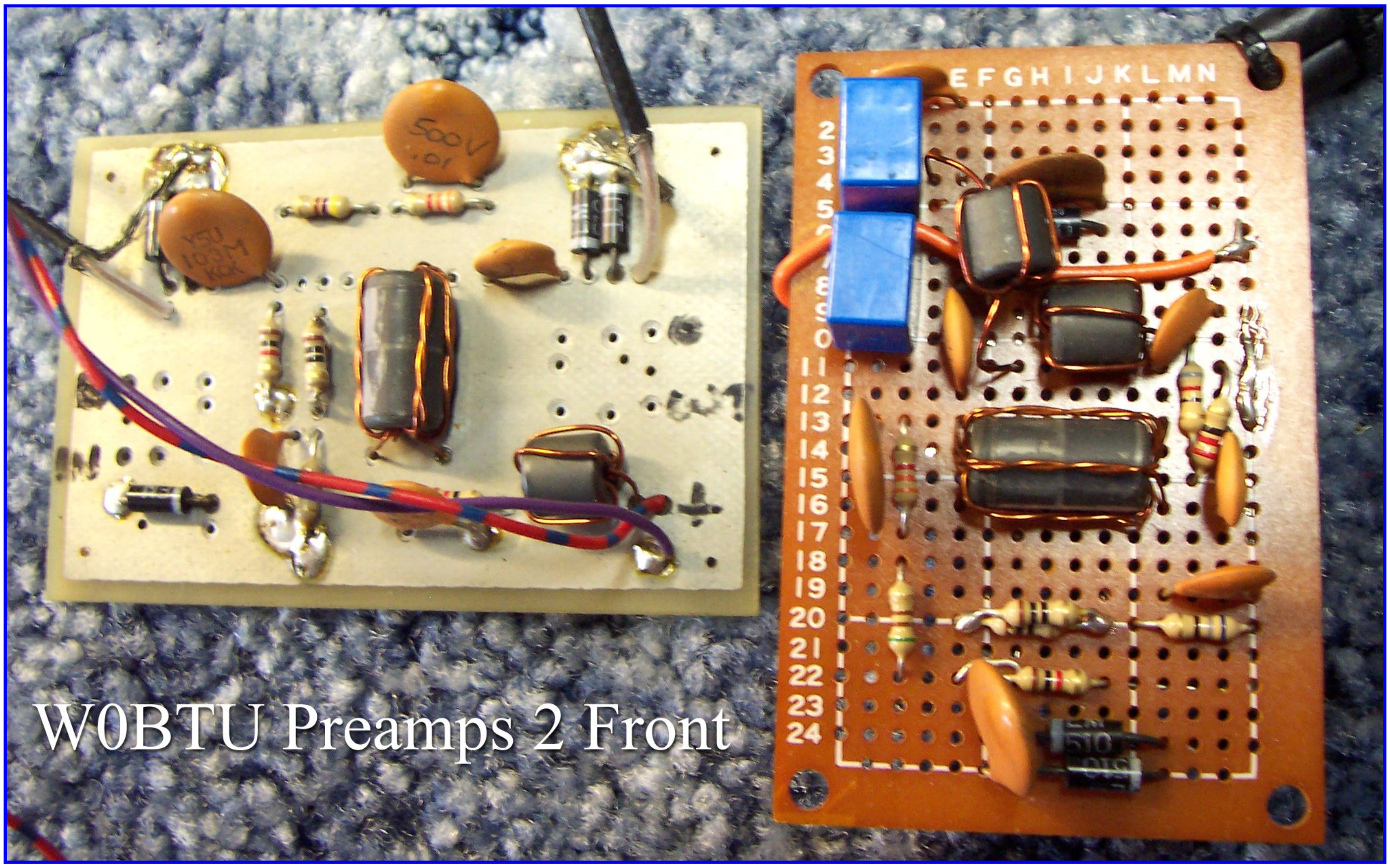
Other W0BTU broadband preamps based on same design, using MRF5812 NPN bipolar transistors. I probably built these sometime before 1995. The relays are to remotely switch the preamp in and out of the signal path.

UPDATED I've modified the one on the right since these photos were taken. They do not (yet) have the W7IUV circuit mod, and out-of-band signals overload it when connected directly to the feedpoint of my Beverage "pointed" NW. That may be partly due to front-end protection diodes conducting. Stay tuned.

Back views



Front views



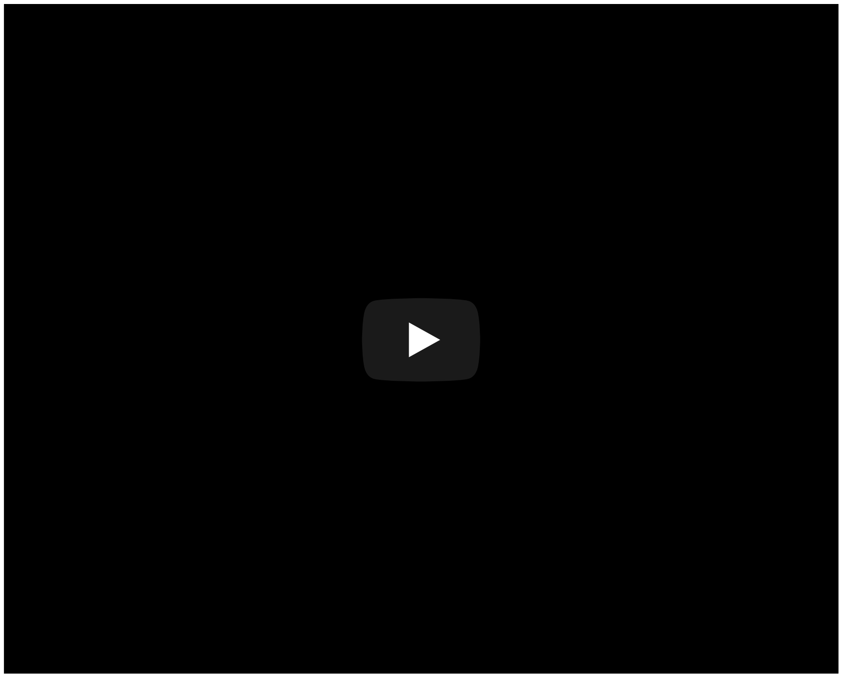
LINKS

www.w7iuv.com
Schematic of improved broadband preamp using 2N5109, based on the same ARRL design. Click on the appropriate link in the left column on Larry's site to view his preamp page.

[Transistor data sheets]()

www.w8ji.com/receiving.htm
Low noise receiving antenna info

www.kitsandparts.com/rfamp1.1.php
I haven't tried this or studied it much, but for the price...



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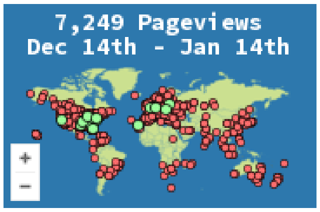
http://www.w0btu.com/W0BTU-broadband-preamps.html - Page created July, 2010 - Last edited 10/11/2015



[DIY Audio Home](http://www.pmillett.com)

LR phono preamp from ETF.13 (solid-state, with no caps in the phono EQ netowrk)

At ETF.13 (European Triode Festival) we held a shootout of LR phono preamps - that is, phono preamps that did not use any capacitors in the phono EQ section.

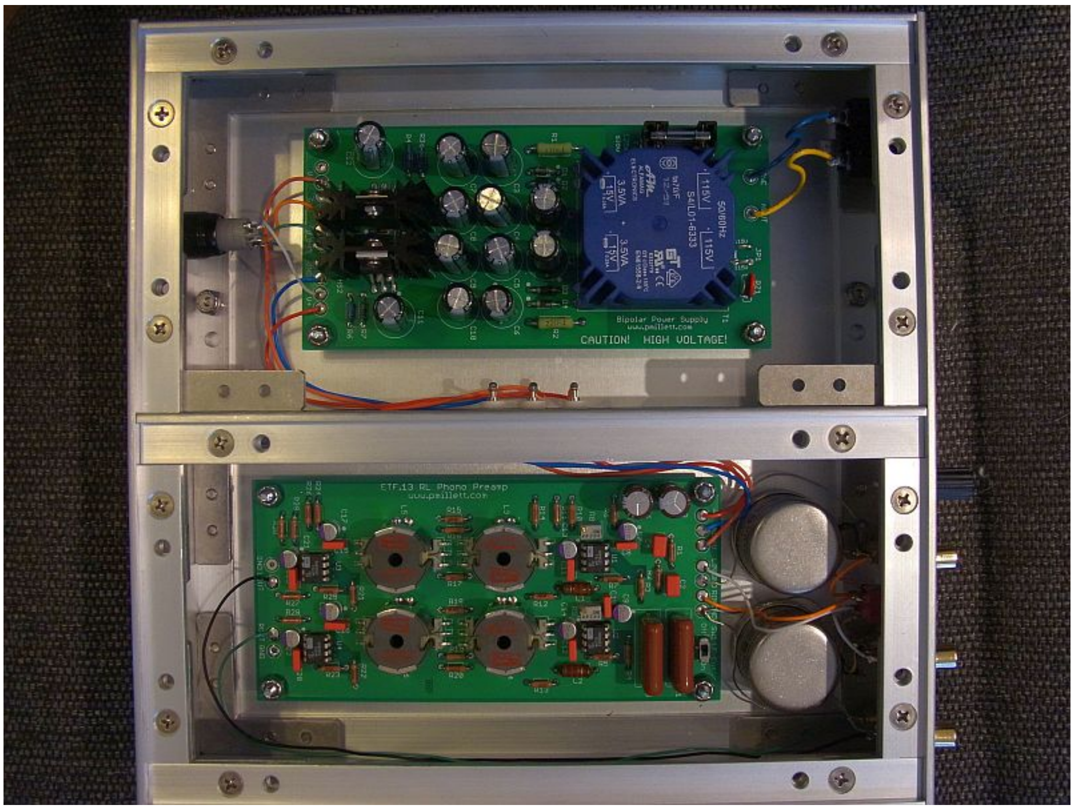
For details on the design process and how this circuit works, please read the presentation from ETF.13 (PDF or PPT).

For the shootout, I designed and built a solid-state preamp.

Recently, after listening to it compared to a couple of different tube and hybrid preamps (some of which I designed), I came to the conclusion that the solid-state LR unit sounded better than the others. I've also had a couple of requests to sell PCBs so that the design can be duplicated. So, I did some re-design to make it a little more DIY-friendly.

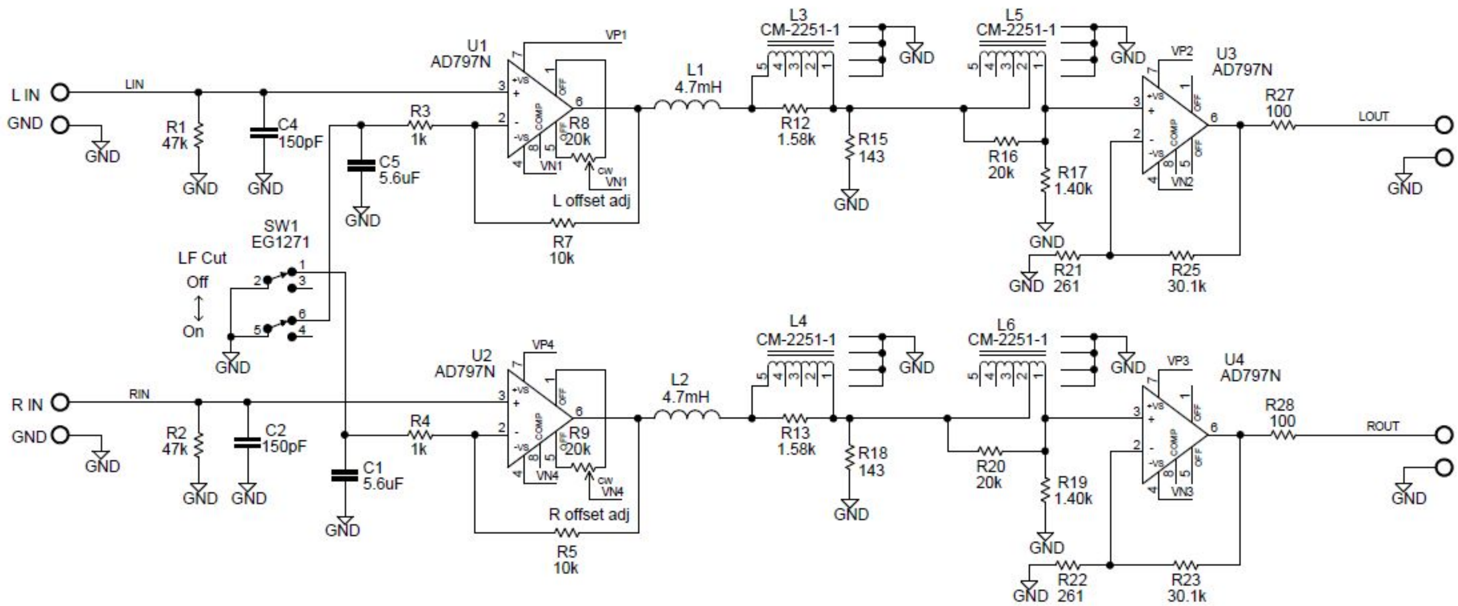
The PCBs will be for sale in my eBay store.

Here is the result!



I removed the power supply and connectors from the preamp PCB, to allow DIYers to do things their own way. I also designed a companion PCB to implement a small opamp power supply (+/- 15V @ 5 watts or so). For my unit, I had [Landfall Systems] make me a "split" chassis, with two isolated compartments to contain the power supply and the preamp.

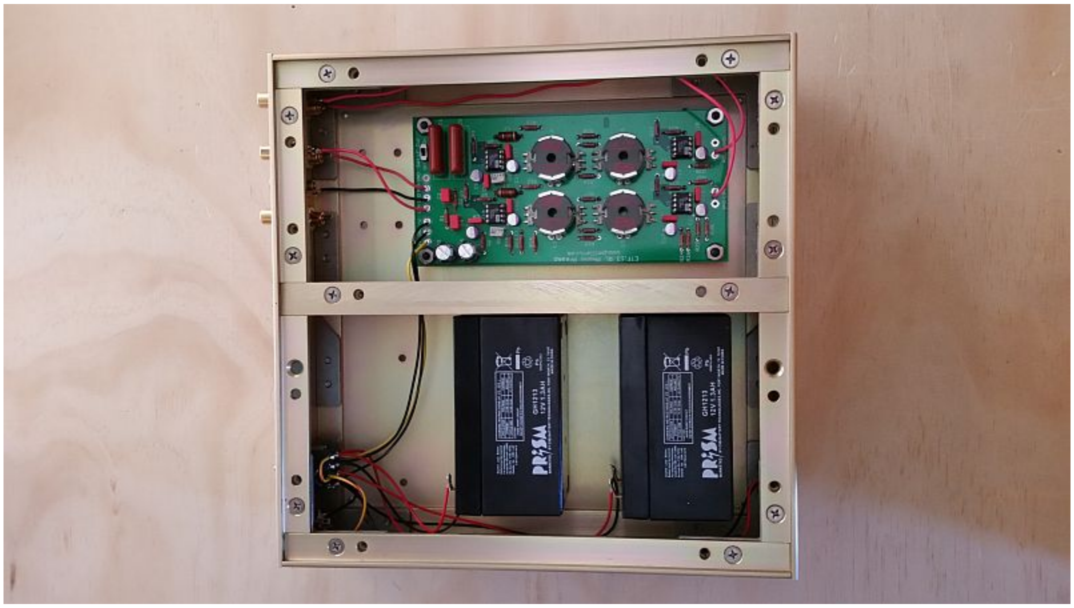
Here is what the schematic looks like (download the [full schematic in PDF] form):



Again, for a full explanation of the design, read the presentation (PDF or PPT).

Here is the parts list (BOM) in PDF or XLS form.

Dave at Landfall built a version using two sealed lead-acid batteries to get +/-12V instead of the power supply. It should run something like 40-50 hours on a charge. That's one way to ensure you have no power supply noise!



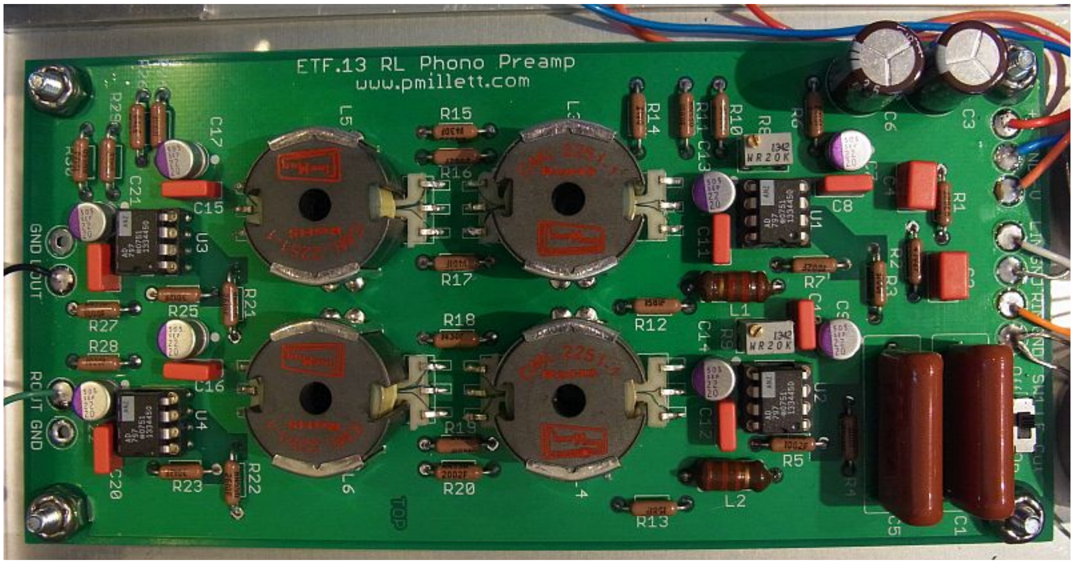
A couple of notes:

The EQ inductors are critical to the performance of the design, and many other components were tweaked to get the right frequency response. They are made by Cinemag. If you use something else you will need to change the resistors to get the right FR.

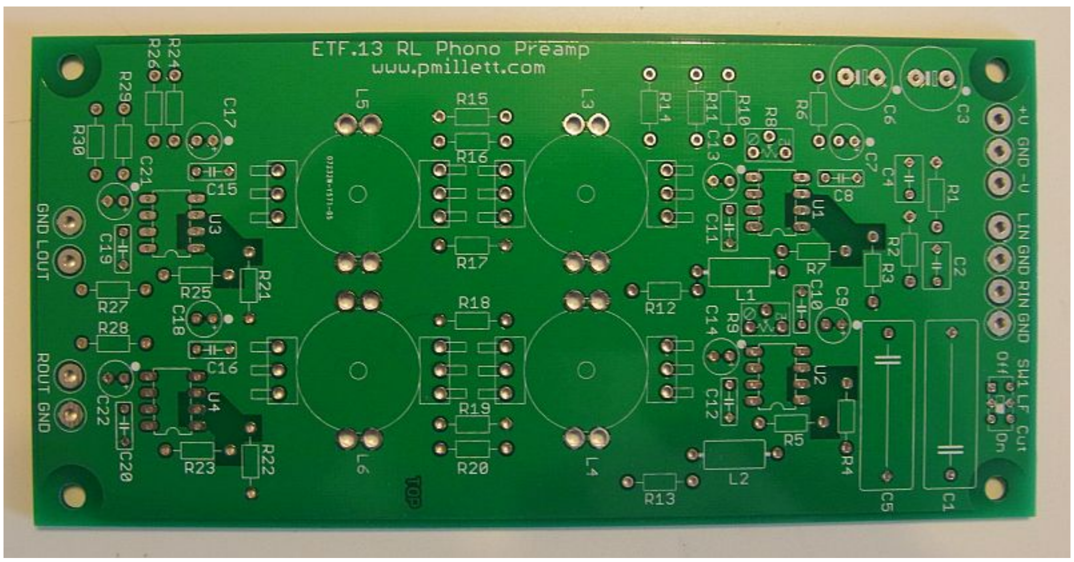
Since there is a large DC gain, I added trimpots to let you null the output DC offset. Adjust the pots (R8 and R9) to get zero volts DC on the outputs with no input signal.

I included the ability to add a LF cutoff around 20Hz. If you don;t want it just jumper C1 and C5 and leave the switch out.

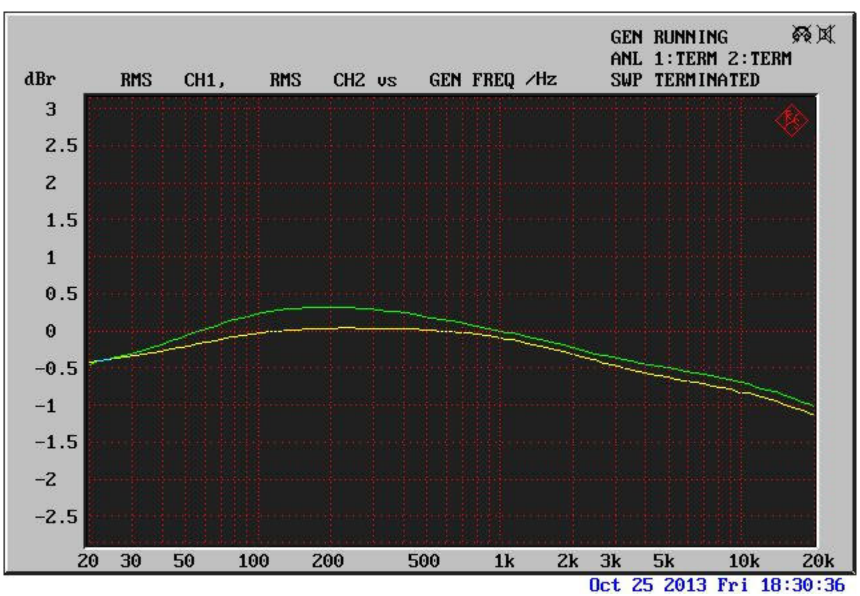
The PCB is 3" x 6.25". You can download a mechanical drawing with mounting dimensions it here.



Note the orientation of the inductors in the photo - it is not obvious from the PCB or inductors!



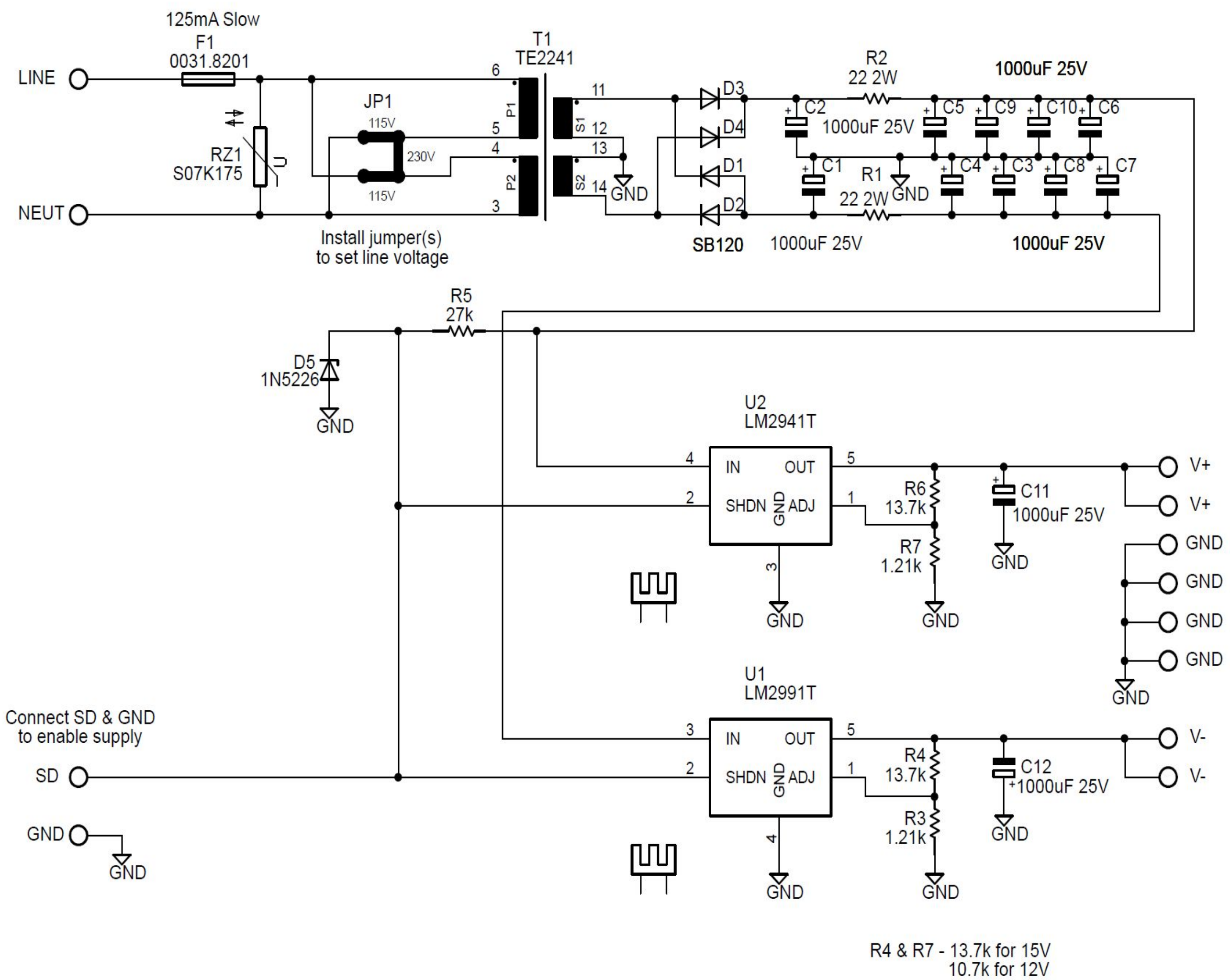
The performance of the preamp is pretty good. Frequency response tracks RIAA within +/-1dB:



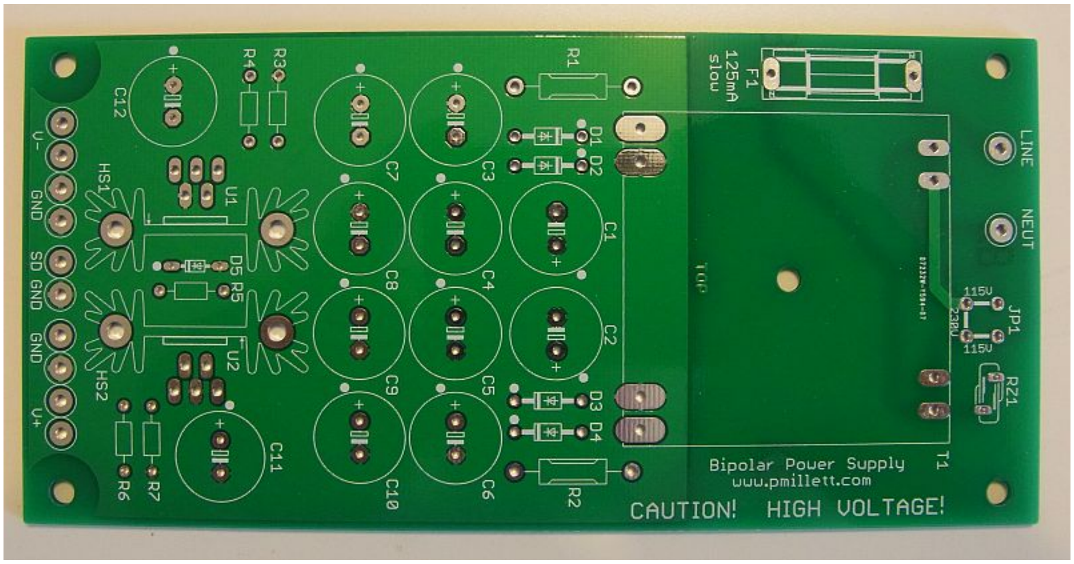
For more performance details, see the ETF presentation.

The preamp uses about 40-50mA at +/- 10-15V. I used an AC power supply, but you can also power it from batteries. Dave at Landfall built a version using two 12V sealed lead-acid batteries...

Here is the power supply (download a PDF schematic):



The PCB is the same size as the preamp. Download a dimensioned mechanical drawing in PDF, and the parts list (BOM) in PDF or XLS



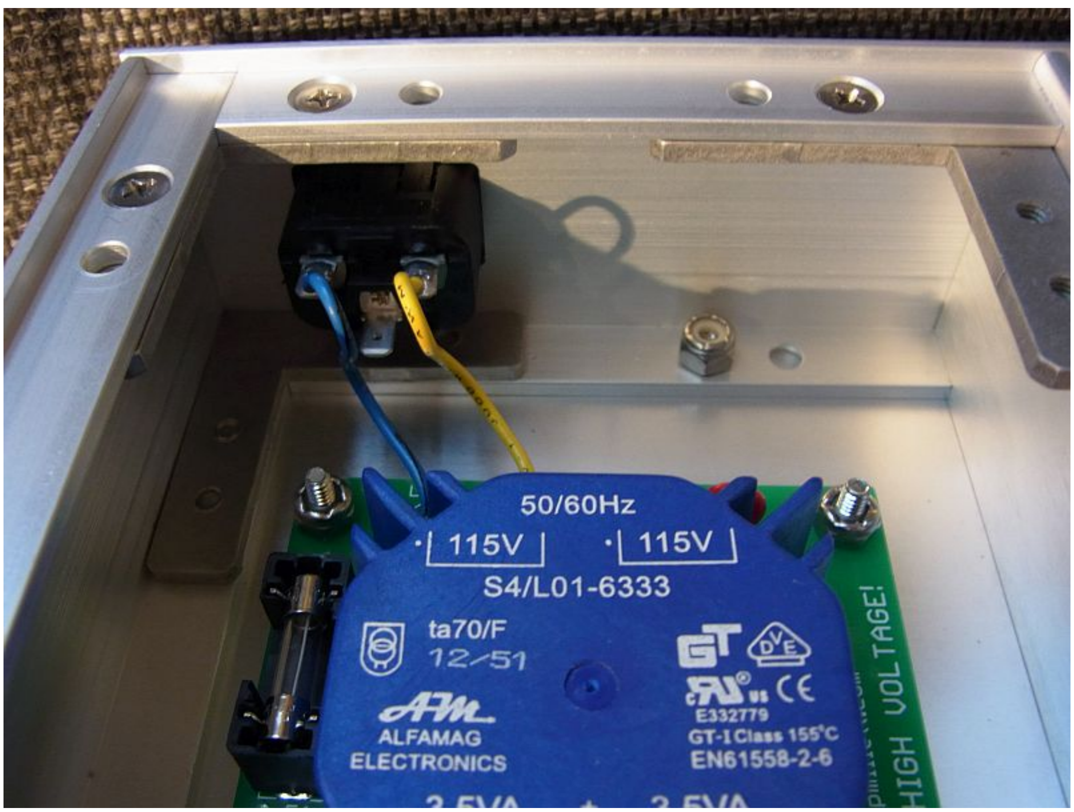
Some more details about how I built this...

I broke a lot of rules, many of them my own, building this preamp.

The first thing you might notice is that I did NOT ground the chassis to the mains ground! Yes, this is potentially dangerous, and I don't recommend that you do it this way! For safety, it is always best to connect the chassis to the AC mains ground. That way, if there is ever a short between the AC line and the chassis, it will trip the breaker and not energize the chassis.

That said... since this is a low-voltage design, the only hazardous voltage is the AC line connection itself. The transformer used here qualifies as "reinforced" insulation, so the secondary side is safe. The only risk is a short from the AC line to the chassis. To me this is a manageable risk so I decided to not ground the chassis.

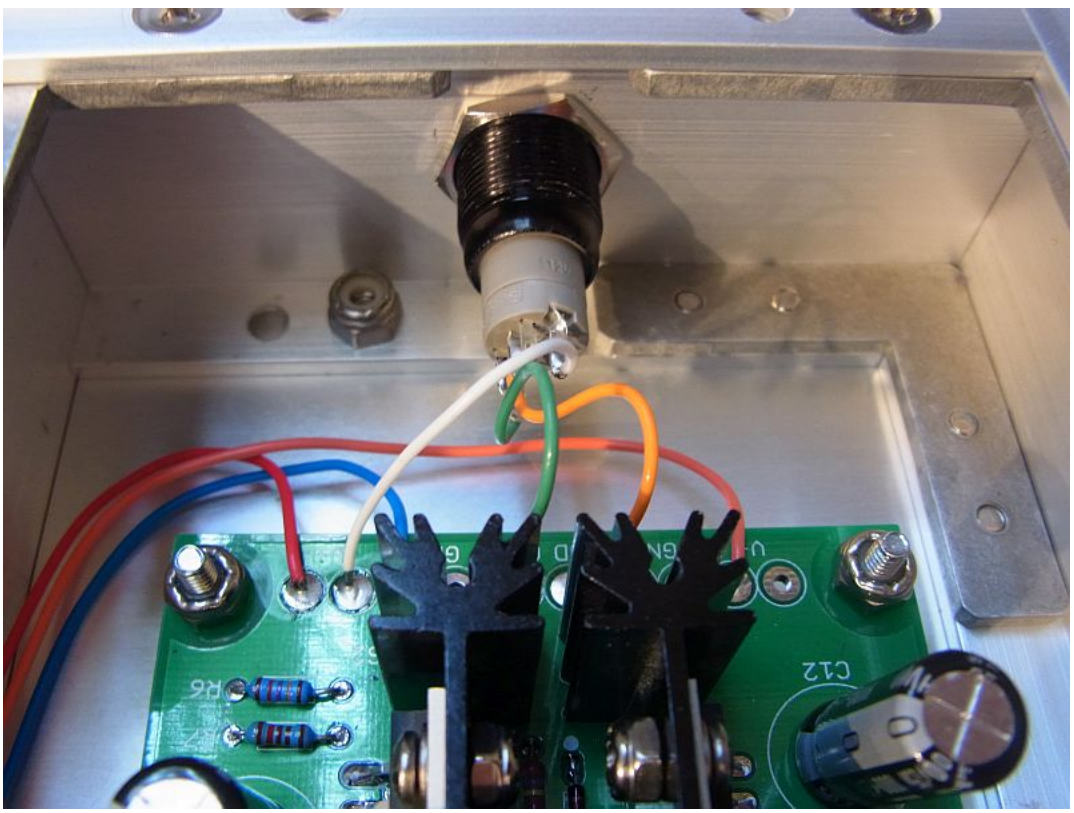
I recommend that you DO NOT DO THIS... if you do, you need to understand and accept the risks! As my Dad used to tell me all the time when I was a kid, DO AS I SAY, NOT AS I DO!



By the way, part of the reason I did this - and why I do not have an EMI filter or filtered IEC connector - is that in some cases the AC mains ground connection in a preamp can generate a ground loop that makes things noisy. And also because I wanted the chassis to be grounded to signal ground:

Yes, all the RCA connectors are connected directly to the chassis without insulation! Another rule broken. Just like in the olden days, the chassis here is ground. It is also plated with clear chromate, not anodized, so it is all very conductive.

A toggle switch on the back panel selects either direct inputs for a MM cartridge, or the output of a pair of [Sowter](http://www.sowter.co.uk) MC step-up transformers for a MC cartridge.



The power supply does not have a switch in series with the AC line. I used the shutdown function of the voltage regulator ICs to provide a power on/off (actually on/standby) function. To enable the supply, you short the "SD" pad on the PCB to GND. I used an illuminated push switch from eBay to do this. The LED is powered from +15V.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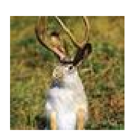
(https://cdn.instructables.com/FWO/IOSL/EWX11ETP/FWOIOSLEWX11ETP.MEDIUM.jpg)

About This Instructable


Jack A Lopez (/member/Jack+A+Lopez
Follow 76
(/member/Jack+A+Lopez/)

Bio: I've built some weird stuff over the years, but most of that stuff has remained

Like the Jedi of the Old Republic who constructed their own lightsabers, each customized to the needs and style of its owner, many Instructables members build their own soldering irons, or at least heavily modify them. Last time I checked there were approximately one jillion instructables on the subject of homemade soldering irons.

A well constructed lightsaber is, according to Wookiepedia (http://starwars.wikia.com/wiki/Lightsaber) , a Jedi's "single perfect weapon that he or she would keep and use for a lifetime."

If only I had such a "perfect" soldering iron that would last forever! In my experience, soldering irons are reliable enough, but far from perfect. The part of the iron that is consumed the fastest is the tip. Soldering iron tips wear down, burn up, diffuse into the solder, or something... Honestly I'm not certain where the mass of the tip goes. Intuition, and the law of conservation of mass+energy, tell me it has to go somewhere. *Everything goes somewhere.* Anyway, all I know for sure is that I start out with a perfect well-tinned tip like a shiny sharpened pencil, and several hours later I end up with a crusty burned-looking stub. Hence the motivation to replace the tip every now and again.

The soldering iron tips created in this instructable are made starting from 6 AWG solid copper electrical wire, and these tips are are approximately 4 mm (5/32 inch) in diameter. In this instructable, I show how to make two styles of 4mm tip, the slidey-style, and the screwy-style.

Step 1 takes a closer look at these two styles of soldering iron tips.

Step 1: A Tale of Two Tips

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The picture below shows the two styles of 4mm (5/32 inch) soldering iron tip that I'll be making.

If your soldering iron doesn't look like one of these, well um... I never said this instructable would cover *every* soldering iron under the sun. So uh... what you

unseen by the world outside of me and a ...
More » (/member/Jack%20A%20Lopez/)

More by Jack A Lopez:

see here is what you get.

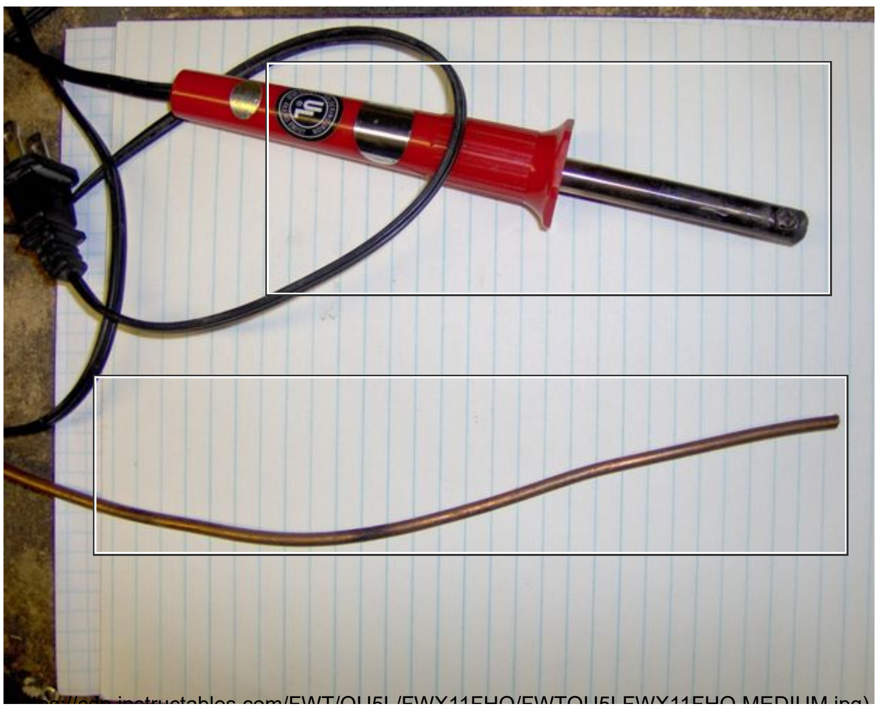
I call the first one "slidey-style" because the tip slides in and out of the iron. This design uses a fat screw, set into the side of the iron, to secure the tip, keeping it from sliding out while soldering.

The second, I call "screwy-style" since the tip is threaded, and it screws in and out of the soldering iron.

I definitely prefer the slidey-style, for a number of reasons: (1) The slidey-style tips are easier to adjust. (2) This system holds the tip more securely. (3) The slidey-style tips are much easier to make.

So if you're new to this soldering iron stuff, and you're wondering which style is better. The answer is the slidey-style is superior, IMHO.

Step 2: Materials and Tools Used in This Instructable



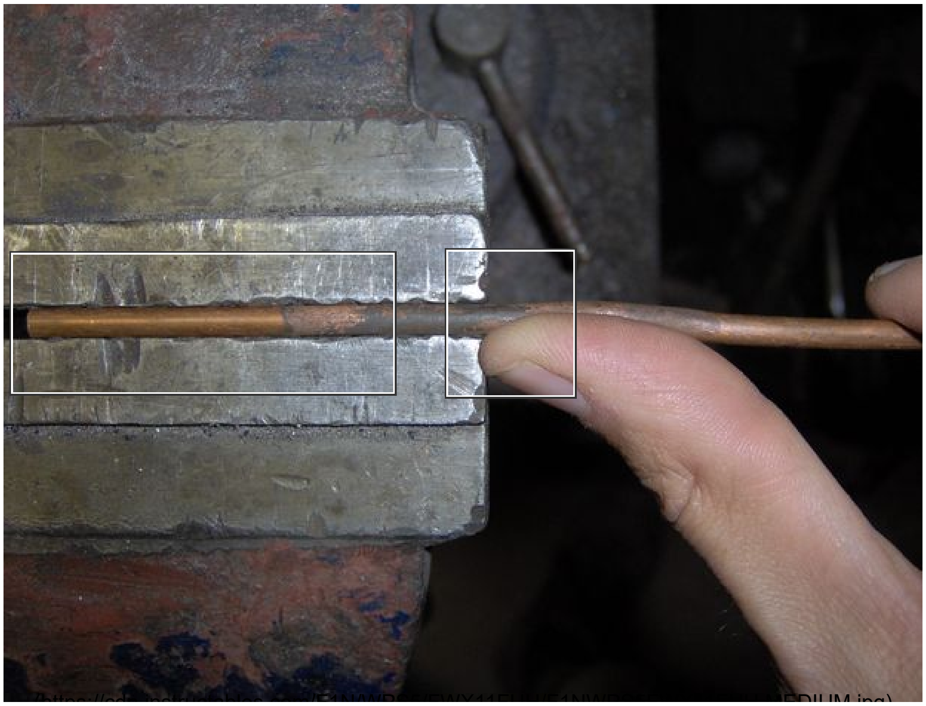
material(s)
soldering iron in want of tip replacement
several cm or inches of 6 AWG solid (not stranded) copper electrical wire.

tool(s)
vise
hacksaw
small drill press
file, sandpaper, steel wool, etc

Note: The steps for making a threaded tip will require a die to make the threads. The thread for my screwy-style tip is metric 4mm-by-0.75, and this is the same thread as RadioShack(tm) part #64-2073

Regarding substitutions for materials or tools, if you want to use pliers instead of a vise, brass instead of copper, etc, that's cool ese, with the usual caveats about YMMV.

Step 3: Straighten the Wire.



The goal of this step is to take wire that may be crooked, and straighten it out. I use a vise for this task.

One important thing to keep in mind is the (very pure) copper used for electrical wire is somewhat soft, so if you try really hard you can crush it with the vise, and that would be undesirable. You want to hold the piece in place without marring or squashing it too much.

The simple act of closing the jaws will straighten the wire a little bit, but most of the fine adjustment is done by hand, bending the wire at the point where it enters-exits the side of the vise. The way I do this is by imagining a perfect straight line running right between and parallel to the jaws of the vise, and then bending the wire back towards this line if the wire veers away from it.

In the picture below I'm working on the wire where it touches the right side of the vice, just in that spot.

When that tiny segment looks straighter, I open up the vise and move the whole piece to the left a little bit, and clamp it down again. Then I straighten the next perceptible segment. As I do this, the wire to the left of where I'm working gets progressively straighter.

Then it's pretty much lather, rinse, repeat, until the wire looks like it's straight enough.

Step 4: Cut Off a Chunk.

Cut of a chunk of the newly straightened wire using ye olde hack saw.

Every good hacker should have a hack saw. It's a tool that comes in handy.

I think the length of this chunk was approximately 65 mm or 2+1/2 inches.

The size will depend on the depth of the hole in the soldering iron it is intended to fill.

Step 5: Load the Chunk Into the Drill Press.

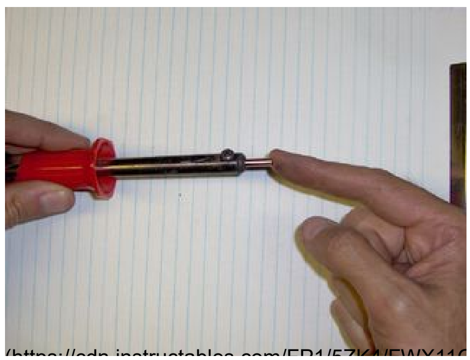
(https://cdn.instructables.com/FR6/UZZC/FWY11C2B/FR6UZZCFWY11C2B.MEDIUM.jpg)

The goal here is to grind and shape the piece while the drill press is turning it. The process is sort of like using a lathe, except everything has been turned vertical instead of horizontal.

It's hard to tell from these pictures, but in all except the first and last pictures below, the spindle is actually spinning while I grind at it with the file, sandpaper, steel wool, etc.

The camera does a good job of capturing an instant in time. While working the piece I don't see what the camera sees. I just see a blur because the spindle is moving so quickly.

Step 6: Slim Down the Tip Diameter.



In the first picture, the cylindrical tip is *just a hair* too wide to fit into the body of the soldering iron.

So I load it back into the drill press, and I grind it down just a little bit, uniformly reducing the diameter the same amount across the length of the cylinder. This of course involves stopping to flip it upside down, to grind the part I couldn't touch the first time because the jaws of the chuck were in the way.

In the last picture, I check the fit again, and the tip slides neatly inside the body of the soldering iron.

BTW, 6 AWG wire (six gauge wire) is almost not exactly 4mm in diameter. It is 4.115 mm in diameter.
See: http://en.wikipedia.org/wiki/American_wire_gauge
(http://en.wikipedia.org/wiki/American_wire_gauge)

Also the spec for the soldering iron might not be 4mm. It might be 5/32 inch, which is 3.969 mm

Step 7: Make It Pointy.

Want the tip to be pointy. So it's back to the old grind, er, so to speak.

Second picture shows the soldering iron and its new finished tip side by side.

Step 8: Steps for a Threaded Soldering Iron Tip

Make a nice cylinder. (Step 9. Similar to step 5)
Make threads. (Step 10)
Make pointy end. (Step 11. Similar to step 7)

Step 9: A Nice Little Cylinder

This little cylinder is about 2.5 cm (1 inch) long. It is destined to become a screwy-style soldering iron tip.

Step 10: Making Threads

For this step its ok /necessary to really clamp the piece in vise tightly. I need to keep it from turning as I cut the thread into it. Marring the copper is not an issue because this spot will be ground away into pointyness in the next step.

I'm not sure what the verb is for cutting threads on the outside of a rod. I think it's "thread". It's not "tap". That's for holes, and the tool that does it is called a "tap". In this case the tool is called a "die", but I'm certain the verb isn't also "die", as in, "Here, could you die this rod for me?"

"Gee, I dunno boss. Looks like it's already dead."
;-P

BTW, the size of this thread is M4-by-0.75. That's 4mm with a pitch of 0.75. At full res, you can just barely see the inscription on the die in the second picture.

Step 11: Make the End Pointy - Trickier This Time

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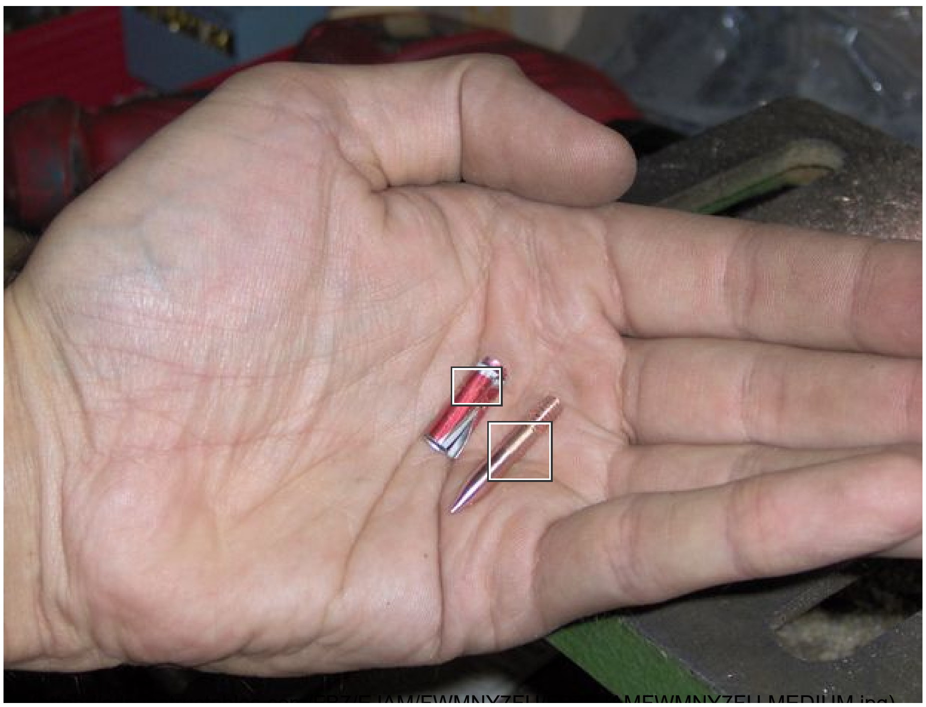

Now it's back to the drill press to make the end pointy. This is pretty much the same trick as shown before in Step 7.

The thing that is different this time is that I want to tighten the chuck right on top of my pretty newly cut copper threads. I don't want these threads to be crushed by the jaws of the chuck, so I have come up with a little contrivance to protect them. It's a little rolled up piece of beer-can-aluminum that goes around the outside of the piece to protect it by evenly distributing the forces of the chuck jaws.

Step 12: Done

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And that's pretty much it, folks. These last two pictures show the slidey-style iron, and the screwy-style iron, side by side with their new tips

Step 13: Brass Tips

You can also make soldering iron tips out of brass. The brass tips seem to last longer, but they don't conduct heat as well as pure copper.

The thermal conductivity of brass is only about 1/4 that of pure copper. See:
http://www.engineeringtoolbox.com/thermal-conductivity-metals-d_858.html
(http://www.engineeringtoolbox.com/thermal-conductivity-metals-d_858.html)
http://hyperphysics.phy-astr.gsu.edu/hbase/tables/thrcn.html
(http://hyperphysics.phy-astr.gsu.edu/hbase/tables/thrcn.html)

Comments

Yonatan24 (/member/Yonatan24/) 2016-03-29 Reply

Hi, I've added your project to the *"Beginners Guide to Soldering"* Collection

This is the link If you are interested:

https://www.instructables.com/id/Beginners-Guide-to...
(https://www.instructables.com/id/Beginners-Guide-to-Soldering/)

Jack A Lopez (/member/Jack+A+Lopez/) ▸ Yonatan24 (/member/Yonatan24/) 2016-03-29 Reply

Wow! Thank you.

Yonatan24 (/member/Yonatan24/) 2015-09-21 Reply

I don't have all of he tools that you have but I will definitely try that in an emergency situation!

Also, If you solder another wire, Won't the tin/lead stick only to the tip of the soldering iron?

Jack A Lopez (/member/Jack+A+Lopez/) ▸ Yonatan24 (/member/Yonatan24/) 2015-09-23 Reply

The solder flows, and it sticks to anything hot that solder likes to stick to.

The first time a new copper tip is used, you can cover the whole thing with a layer of solder. Then a thin layer of solder stays stuck to the tip, forever, almost.

Actually the copper tip itself slowly dissolves in the solder, and after several hours of use the copper tip errodes, changes shape, eventually becomes unusable. Although the rate at which the tip dissolves depends on temperature, so running the iron at a lower temperature can mitigate the errosion of the tip.

joseho (/member/joseho/) 2015-08-14 Reply

Great instructable. But if you add one step for electroplating the tips with nickel, then you can make them long lasting like commercially available ones. Thanks!

turbiny (/member/turbiny/) 2015-03-26 Reply

there is another type where the point is hollow in the middle so the heater core will be directly in the tip and its held by a screw like over the tip.
like this: http://www.upcraft.it/wp-content/uploads/2010/05/3-keep-those-soldering-iron-tips-shiny.jpg

Jack A Lopez (/member/Jack+A+Lopez/) ▸ turbiny (/member/turbiny/) Reply 2015-03-28

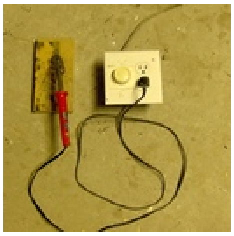
Thank you for sharing that.

Jack A Lopez (/member/Jack+A+Lopez/) 2009-07-12 Reply

Also maybe worth mentioning:

I use a lamp dimmer to run my soldering iron at less than full power, with the belief that this makes the tips last longer.

Some instructables on the subject of lamp-dimmer style temperature throttling for soldering irons:
https://www.instructables.com/id/10ish_DIY_Variable_Temp_Soldering_Iron_Contro
(https://www.instructables.com/id/10ish_DIY_Variable_Temp_Soldering_Iron_Contr
https://www.instructables.com/id/Recycling_your_old_dimmer_switch_as_a_variable
(https://www.instructables.com/id/Recycling_your_old_dimmer_switch_as_a_variab



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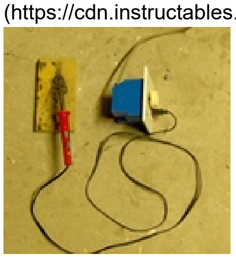


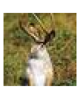
(https://cdn.instructables.com/FQK/W8E7/FX23V764/FQKW8E7FX23V764.LARGE.jpg)

nroslm (/member/nroslm/) ▸ Jack A Lopez (/member/Jack+A+Lopez/) Reply 2015-02-11

Works great if your stuck with a 40W iron.

michael.neidich (/member/michael.neidich/) 2014-10-15 Reply

Thanks very much for the #6 ground wire of copper. It works great, but do you know a way to make a conical point on the round wire? I make a 4-sided pointy tip with the Dremel, and then filed it conical. Is there an easy way? Mike



Jack A Lopez (/member/Jack+A+Lopez/) ▸ michael.neidich (/member/michael.neidich/) 2014-10-19 Reply

The first picture in Step 7 shows me grinding a cone shaped tip onto a short piece of copper wire. The piece of wire is held in the chuck of my drill press, and it is spinning, so pressing a file to it grinds away material in a way that is radially symmetric, kind of the same way a lathe works.

In this picture, I am holding a block of wood in one hand and a file in the other hand, with both pressing against the spinning copper. The reason for this technique is to sort of balance the forces on the copper work piece. Copper wire is soft. With just the file alone pressing on it, the wire has a tendency to bend somewhat. Essentially, the wood block prevents the copper wire from bending while it being ground down by the file.

Someone else was asking about this, in a comment below this one, and I drew some arrows on that picture, here,

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(https://cdn.instructables.com/FJM/VQCB/FX23V4KL/FJMVQCBFX23V4KL.LARGE.jpg)

to sort of indicate the direction of the pressing forces, since you can't "feel" force in pictures, because a picture is a visual thing.

eric m (/member/eric+m/) 2011-04-25 Reply

This is only a temp fix.

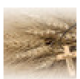
Copper/brass will be eaten by flux & solder. It's a pain to always tin a brass tip every 30 seconds.

Weller uses chrome on iron. It's superior.

Maybe you should find a steel or iron bit instead.

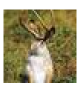
adamvan2000 (/member/adamvan2000/) 2009-07-10 Reply

OK, this may sound odd, but what about carbon rods, like the ones found in el-cheapo dollar store batteries? Will they conduct enough heat to be useful? I know they work great for those DIY cold-heat irons, but it just occurred to me how easy it'd be to make a new one of those. After all, to point them, all I do is use a pencil sharpener. May try this on my iron, just for kicks. ~adamvan2000



adamvan2000 (/member/adamvan2000/) ▸ adamvan2000 (/member/adamvan2000/) 2009-07-10 Reply

OK, first test says nope. All it did was smoke steadily, which I'm guessing was battery chemicals. Good thing for proper venting. I'm guessing that the carbon rods simply dissipate the heat too quickly for this to be an effective replacement for the regular or copper ones. ~adamvan2000



Jack A Lopez (/member/Jack+A+Lopez/) ▸ adamvan2000 (/member/adamvan2000/) 2009-07-10 Reply

This carbon rod idea seemed so zany, I thought I'd try it too. The carbon rod from a "heavy-duty" AA battery does happen to be just the right size (4mm diameter) to fit in my slidey-style soldering iron. Plus it was easy enough to file a conical point on to it. However, this new carbon tip doesn't conduct heat very well. I could barely get it to melt the solder.

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(https://cdn.instructables.com/FRR/YX2S/FWYHUYDH/FRRYX2SFWYHUYDH.LARGE.jpg)

eddyspaghetti (/member/eddyspaghetti/) ▸ Jack A Lopez (/member/Jack+A+Lopez/)

2009-10-23 Reply

Interesting concept, and at first blush it seems carbon would be much less susceptible to oxidizing than traditional nickle or chrome tips, or at least what oxidation does occur, it would dissipate as a gas (CO or CO2 depending upon conditions I believe) which the occasional tip shaping is a lot less bothersome than constant tip wiping, tinning, etc etc not to mention the terrible performance an oxidized tip provides . That property alone seems worthwhile enough to not give up on the concept just yet.
If the thermal conductivity is good but the problem is in thermal retention, it seems the idea is already halfway there. I don't have any graphite off hand of a substantial enough diameter, but maybe someone who does could give this idea a try;
Turn (or file) graphite to desired profile, then chuck it from the other end if on a lathe or work some vise voodoo on a drill press, use peck drilling to form a cavity. Next, using either copper or iron most likely (for their ability to retain heat) match to the profile of the cavity in the graphite, possibly adding some groves to accommodate for thermal expansion if cracking occurs with a tight match. Basically the carbon tip idea with a metallic core. If anyone tries it out I'd be interested to hear how it works out, or if someone has the graphite but dosnt have the tools hit me up and I'll turn a few for both of us if it works out.
-Ed

---

adamvan2000 (/member/adamvan2000/) ▸ Jack A Lopez (/member/Jack+A+Lopez/)

2009-07-11 Reply

Hey, we tried, right? It's funny, as the thermal conductivities of carbon and copper are 140 and 200, respectively, so they don't seem that far off. I seem to remember now reading somewhere that carbon dumps the heat too fast to be used this way, unless you're running a current through it and using it like a cold-heat soldering iron(one of my next projects). ~adamvan2000

---

unclelar (/member/unclelar/)

2009-07-12 Reply

The term used for cutting the threads,is simply "threading or to thread" an example ;would you thread this rod,or are you done threading that rod .Anyhow, good job on your instructable

---

Jack A Lopez (/member/Jack+A+Lopez/) ▸ unclelar (/member/unclelar/)

Reply 2009-07-12

So we tap threads into a hole with a tap, and we thread threads onto a rod with a die. God, I love the English language.

---

unclelar (/member/unclelar/) ▸ Jack A Lopez (/member/Jack+A+Lopez/)

Reply 2009-07-13

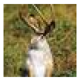
Exactly! Now You've got it.

---

crankyjew (/member/crankyjew/)

2009-07-11 Reply

nice. i can see a drill clamped lightly in the vise as a good alternative for those of us without a drill press. also, copper electrical wire is usually dead soft. have you tried hardening the copper, and/or do you find it necessary?



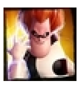
Jack A Lopez (/member/Jack+A+Lopez/) ▸ crankyjew (/member/crankyjew/) 2009-07-12 Reply

I don't do anything to harden the copper, and these homemade copper tips seem to work almost just like the factory made kind. Regarding the softness of copper, that reminded me of something. To keep from bending the piece while grinding, it can be helpful to have something pushing on both sides of it. This is the purpose of the piece of wood seen in some of the pictures.

(https://cdn.instructables.com/FJM/VQCB/FX23V4KL/FJMVQCBFX23V4KL.LARGE.jpg)

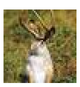
gmoon (/member/gmoon/) 2009-07-11 Reply

There are some really good "tips" in this one... thanks!



jman 31 (/member/jman+31/) 2009-07-10 Reply

Very nice instructable! I just may use this method in the future. I've noticed however that all the tips I use are coated with some sort of silver substance. I have found that they last pretty good until I sharpen and get down to the raw copper, then they seem to burn up pretty quickly. Any idea what that is?

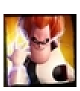


Jack A Lopez (/member/Jack+A+Lopez/) ▸ jman 31 (/member/jman+31/) Reply 2009-07-10

MIght be iron or nickel, with a thin layer of tin on top. Honestly I don't know.

But I recently found this:
http://www.patentstorm.us/patents/5553767/description.html
(http://www.patentstorm.us/patents/5553767/description.html)
It's a 1996 patent for some kind of newfangled soldering iron tip. The "prior art" section mentions problems with soldering iron tip coatings, copper being soluble in tin at high temperatures, etc.

So maybe the legends of delicate tip coatings are true...



jman 31 (/member/jman+31/) ▸ Jack A Lopez (/member/Jack+A+Lopez/) Reply 2009-07-10

Thanks for the reply. I still think your idea is sound. As long as you keep a good point on it whenever you solder. Thanks for sharing!

More Comments

Soldering Iron Tips From 6 AWG Copper Wire by

Jack A Lopez (/member/Jack+A+Lopez/) in soldering (/technology/soldering/)

Download | (/id/Solder...-Copper-wire/) | 13 Steps

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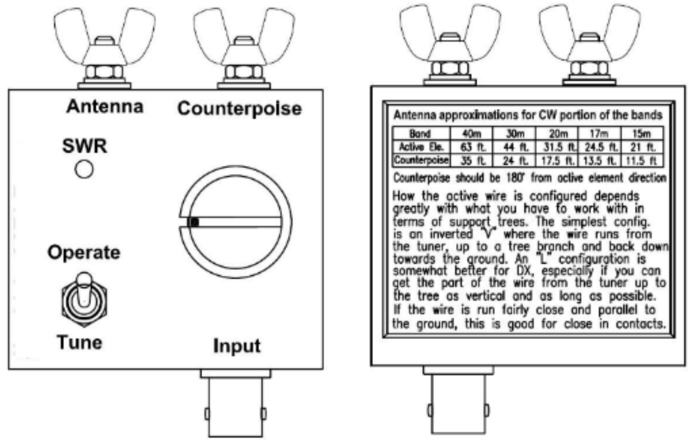
Pacific Antenna 40m – 15m SOTA Tuner



First, familiarize yourself with the parts and inventory the kit using the table below.

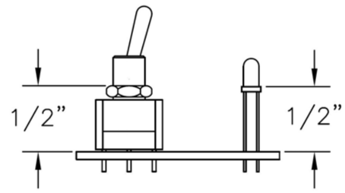
Parts List

Inventory	Component	Quantity	Note
	SWR Indicator Kit	1	SWR Bridge Kit
	T50-6 toroid	1	Yellow toroid core
	Polyvaricon	1	Variable Capacitor
	Polyvaricon shaft screw	1	2.6 x 12mm Phillips pan head screw
	Polyvaricon mounting screw	2	2.5 x 4mm screw
	Washers for mounting screws	2	Lockwashers for polyvaricon mounting screws
	Polyvaricon shaft	1	3/8” white Nylon standoff
	6-32 screw	2	3/4” Stainless phillips pan head screw
	#6 lock washer	2	Stainless
	#6 flat washer	2	Stainless
	6-32 wingnut	2	Stainless
	#6 nylon step washer	2	Nylon, white
	#8 nylon flat washer	2	Nylon, white
	#6 tinned solder lug	2	Solder Lug
	6-32 nut	2	Stainless
	4-40 screw	2	1/4” Undercut flat head
	BNC	1	Female, chassis mount
	1/4" shaft knob	1	Black plastic knob
	#26 magnet wire	24”	Red or Green #26
	Hook-up wire	18”	#22 or # 24 AWG, two colors, 9” each
	SOTA chassis	1	Aluminum, unfinished
	SOTA decal set	1	Waterslide decal sheet

Assemble the SWR Indicator Kit.

Complete assembly instructions for the SWR indicator kit are located on-line at http://www.qrpkits.com/swrindicator.html .

The last component to solder to the SWR board is the LED. Use the above dimensions to locate the lip of the LED.



Adjust the inside nut of the switch, for the correct fit to the chassis so that the LED will just fit through the case when the SWR indicator is installed.

Set the SWR indicator aside, for now as the rest of the assembly is done inside the chassis.

Prepare the chassis

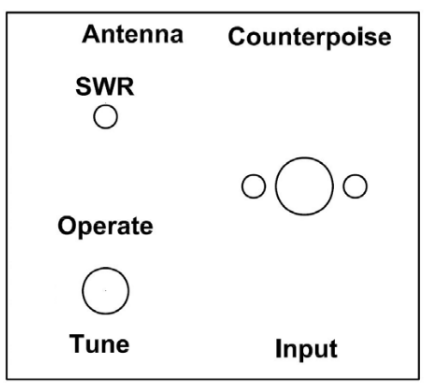
Thoroughly clean the surface of the panel to remove any oils or contamination.

TIP: We have found that moving the decals into position on a bare aluminum chassis is sometimes difficult, due to the brushed surface, so we recommend either painting or pre-coating the chassis with Krylon clear, or a similar clear coating, and allowing the coating to thoroughly dry before applying the decals.

Decal Application

The supplied decals are known as water slide decals. An example video of how to apply these types of decals can be found here: https://www.youtube.com/watch?v=Pr5R9VCNVHU

It is recommended to apply the decals before mounting anything to the chassis.



Use the above picture as a guide for the correct spacing of decals around the holes to prevent any labels being covered by a knob or switch.

Cut out and trim around each group of text or symbols you wish to apply. Trimming doesn't have to be perfect as the background film is transparent.

After trimming, place the decal in a bowl of lukewarm water with a small drop of dish soap to reduce the surface tension for 10-15 seconds.

Using tweezers, and carefully handle decals to avoid tearing. Start to slide the decal off to the side of the backing paper, and place the unsupported edge of the decal close to the final location.

Hold the edge of the decal against the panel, with your finger, and slide the paper out from under the decal. You can slide the decal around to the right position, as it will float slightly on the film of water.
You may find it helpful to use a knife point or something sharp to do this.

When in position, hold the edge of the decal with your finger and gently squeegee excess water out from under the decal with a tissue or paper towel.

Working from the center, remove any bubbles by blotting or wiping gently to the sides. Take your time and do this for each decal.

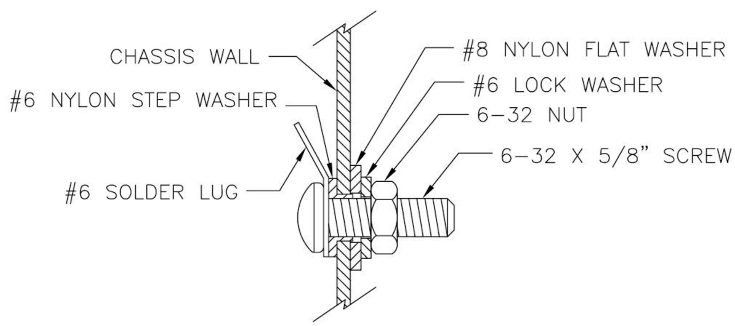
Let the decals to dry overnight, and you can speed up this process by placing the chassis near a fan.

When completely dry, the decals should be sealed and protected by spraying at least two light coats of a clear matte finish, such as Krylon, or other similar products to. It is important to apply only light coats and to allow each coat to completely dry between applications

Once the final clear coat has dried thoroughly, continue as follows:

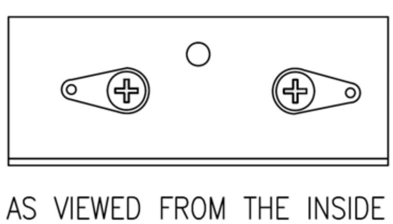
Install the connectors and hardware on chassis

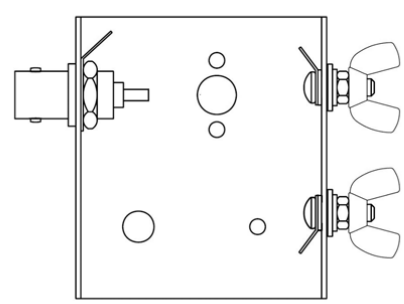
Assemble the two antenna connections and the bnc connector to the chassis cover.



NOTE: The nylon step washers are used to keep the antenna connections insulated from the chassis.

Position the solder tabs as shown below, and angled down slightly, so that the antenna lug does not short against the PEM nut when the case is assembled.





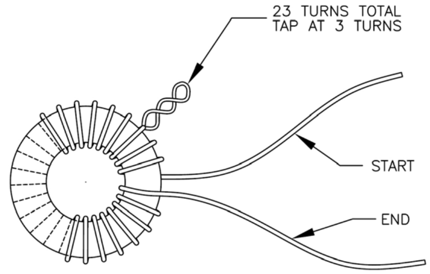
Check that there is no continuity between the solder tabs and the case at this point. This is to verify that the insulating washers were installed correctly.

Wind L1

Using the T50-6 yellow toroid and the enclosed magnet wire.

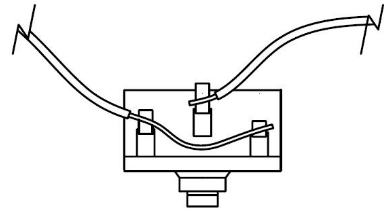
When complete, L1 will have a total of 23 turns, with a tap at 3 turns from the “START” end.

Remember, every time the wire passes through the center of the toroid, counts as one turn.

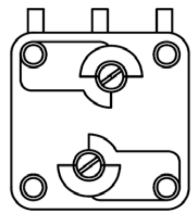


Pre-wire the Poly-varicon

As shown with 2” pieces of the hook-up wire to put the two sections of the poly-varicon in parallel.



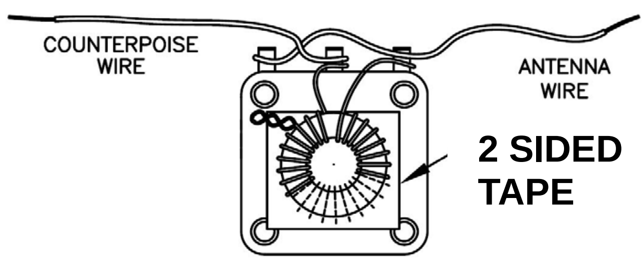
At this time, adjust the small trimmers on the back of the polyvaricon for half engagement.



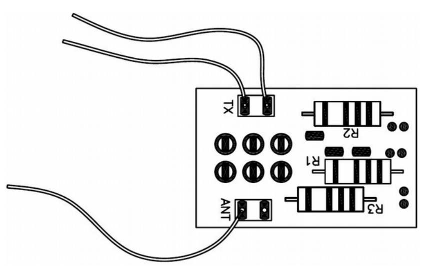
Mount the shaft and center screw provided on the polyvaricon

Put a small piece of double sided tape on the back of the poly-varicon. This will act as a surface to secure the toroid.

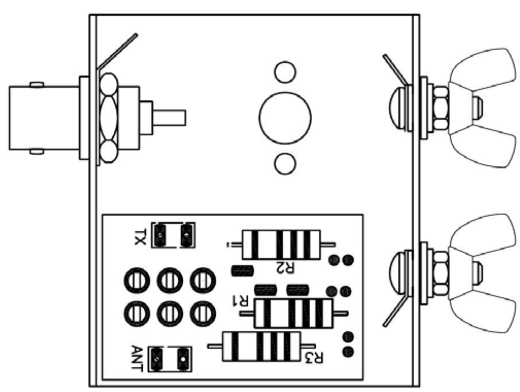
Wire only the two ends of the toroid winding to the poly-varicon as shown, Leave the tap unsoldered for now.

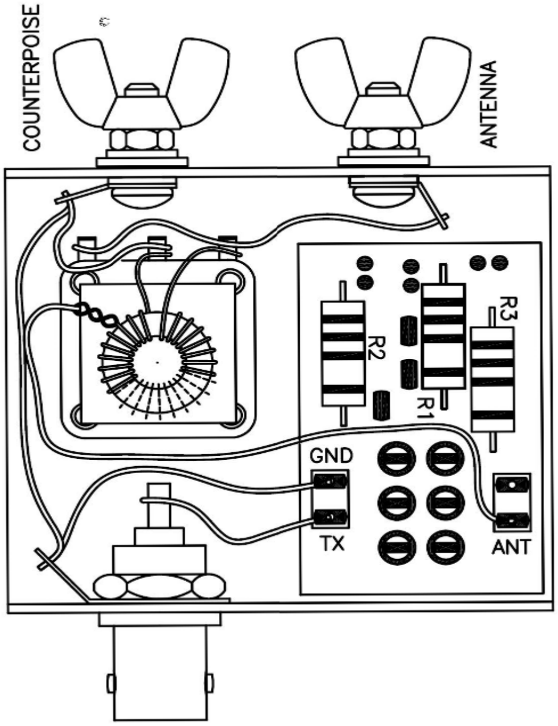


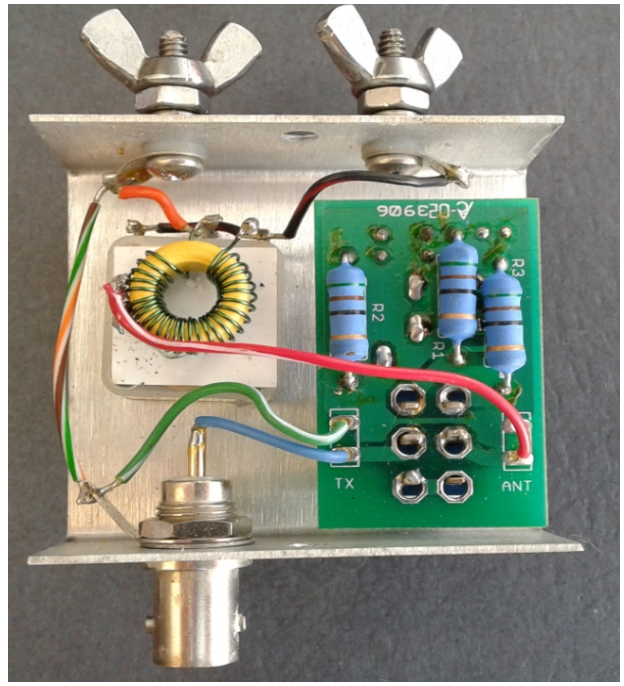
Pre-wire the previously assembled SWR indicator as shown with 3” long pieces of hook-up wire.



Install the pre-wired SWR indicator as shown, and secure it to the chassis with the remaining toggle switch nut.







Final Assembly Steps

The above diagram and photo will assist with making the final connections to complete your SOTA tuner:

Mount the poly-varicon/toroid assembly to the chassis cover with the two 2.5 x 4 mm screws and the supplied lockwashers.

The washers are necessary to provide sufficient clearance for the polyvaricon plates. They are a relatively tight fit and may need to be gently pressed in place.

Solder the wire from the center connection of the poly-varicon to the counterpoise lug.

Solder the wire from the side connection of the poly-varicon to the antenna lug.

Solder the “ANT” wire from the swr indicator to the toroid tap.

Solder the “TX” wire from the swr indicator center connection of the BNC connector.

Solder the “GND” wire from the SWR indicator to the BNC ground lug.

TIP: Before proceeding test with the toggle switch in the “OPERATE” position to be sure there is no continuity between the wingnuts and the case.

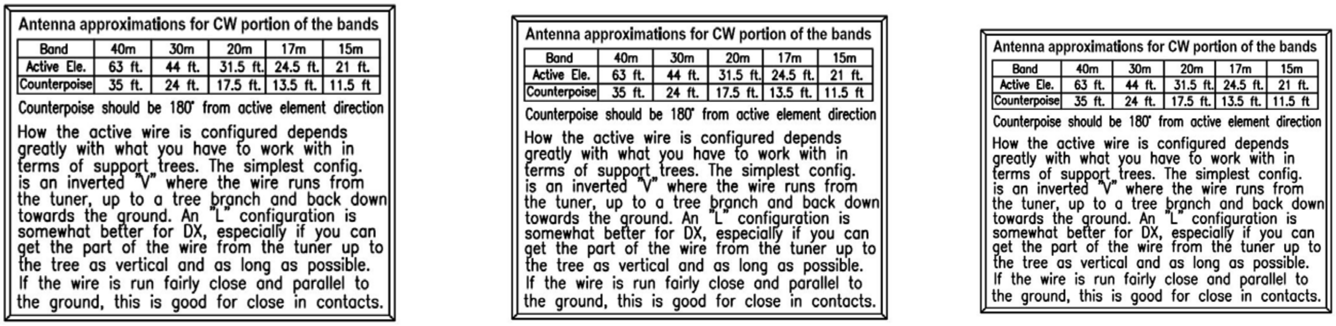
Solder a wire from the BNC ground lug to the counterpoise ground lug.

Fit the bottom half of the case to the top and secure it with the two flat head 4-40 screws.

Install the knob on the poly-varicon shaft using the knob set screw.

Congratulations this completes assembly of your SOTA Tuner!

Optional label for back of case



Antenna approximations for CW portion of the bands

Band	40m	30m	20m	17m	15m
Active Ele.	63 ft.	44 ft.	31.5 ft.	24.5 ft.	21 ft.
Counterpoise	35 ft.	24 ft.	17.5 ft.	13.5 ft.	11.5 ft

Counterpoise should be 180° from active element direction

How the active wire is configured depends greatly with what you have to work with in terms of support trees. The simplest config. is an inverted "V" where the wire runs from the tuner, up to a tree branch and back down towards the ground. An "L" configuration is somewhat better for DX, especially if you can get the part of the wire from the tuner up to the tree as vertical and as long as possible. If the wire is run fairly close and parallel to the ground, this is good for close in contacts.

If you want to have this chart on your tuner, print out the above labels and scale when printing as necessary to fit the bottom of the chassis.

Three sizes are provided to approximate the correct size to fit the case regardless of you printer scaling.

We recommend protecting this label with a piece of clear packaging tape, or peel and stick laminate film.

You can attach it to the back of the case with two-sided tape.

Using your SOTA Tuner

Start with a light weight wire a few inches longer than the lengths suggested for the band you wish to operate and test to see if a good match can be achieved as indicated by the LED completely extinguishing as the tuning knob is turned over its range.   If not, shorten the wire in one inch increments and retest.

Note: The values provided in the table above are suggested starting points, not absolutes and your wire lengths may vary due to many conditions.

Note: Some users use short counterpoises of approximately 0.1 wavelength successfully with endfed half wave antennas.

The condition and nature of the ground as well as the angle of elements in respect to ground, can all affect the overall length wire needed to achieve a good match.

We recommend that you test the SOTA tuner and note what works best for your conditions.

How the wire is deployed will depend on what is available for support such as trees and/or structures.

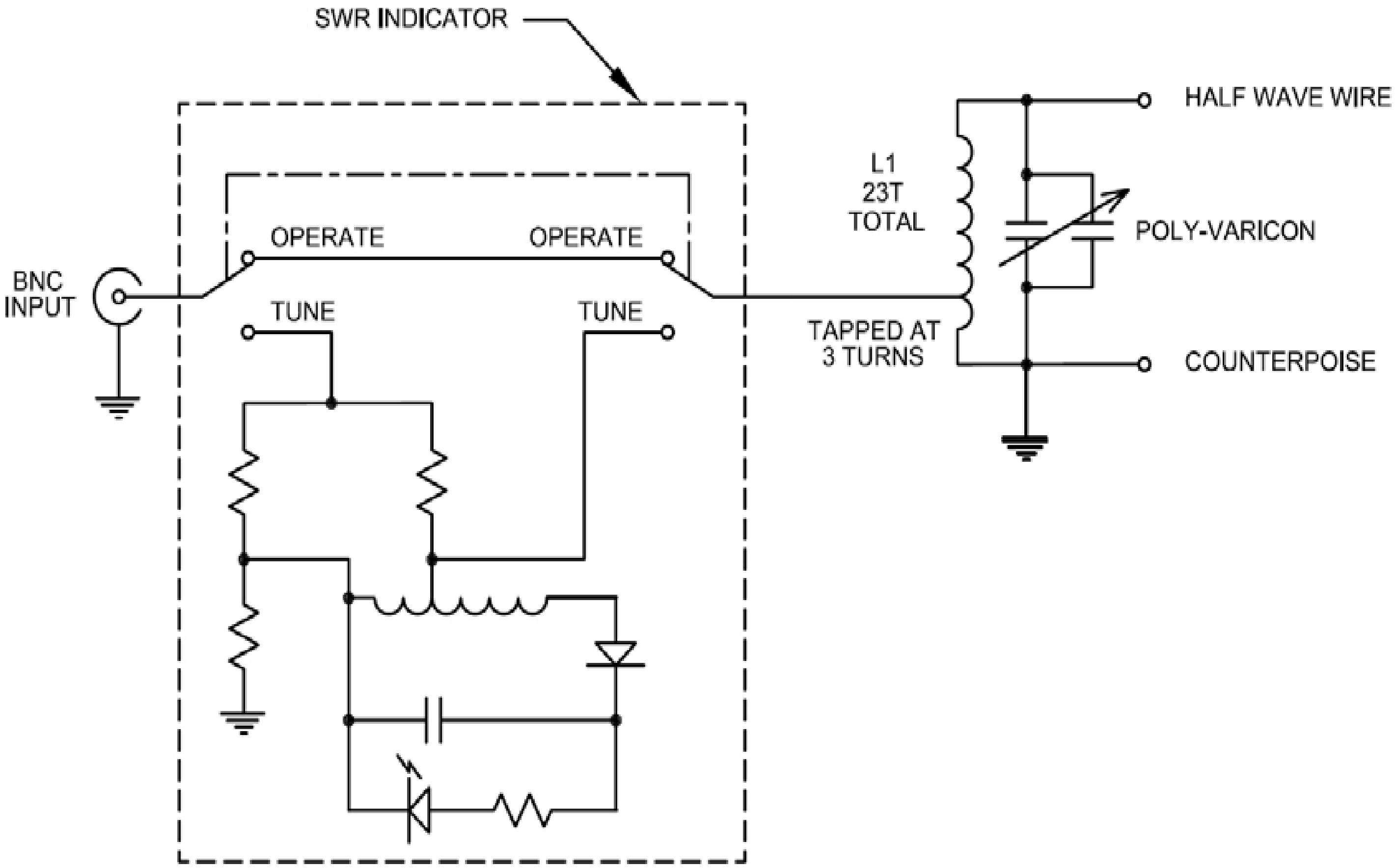
The simplest configuration is an inverted "V", where the active element runs from the antenna connection of the tuner, up to a tree branch, and back down towards the ground.

An "L"configuration for the active element is somewhat better for DX, especially if you can get the part of the wire from the tuner up as vertical as possible.

If the wire is run horizontally and fairly close to the ground, the signal will mostly be directed upward and therefore will be better for close in contacts, especially on the lower frequency bands.

Try to keep the counterpoise 180 degrees from the active element.

Schematic


SWR INDICATOR
BNC
INPUT
OPERATE
OPERATE
TUNE
TUNE
L1
23T
TOTAL
TAPPED AT
3 TURNS
HALF WAVE WIRE
POLY-VARICON
COUNTERPOISE

Radio Frequency Experiment by BH1RBG

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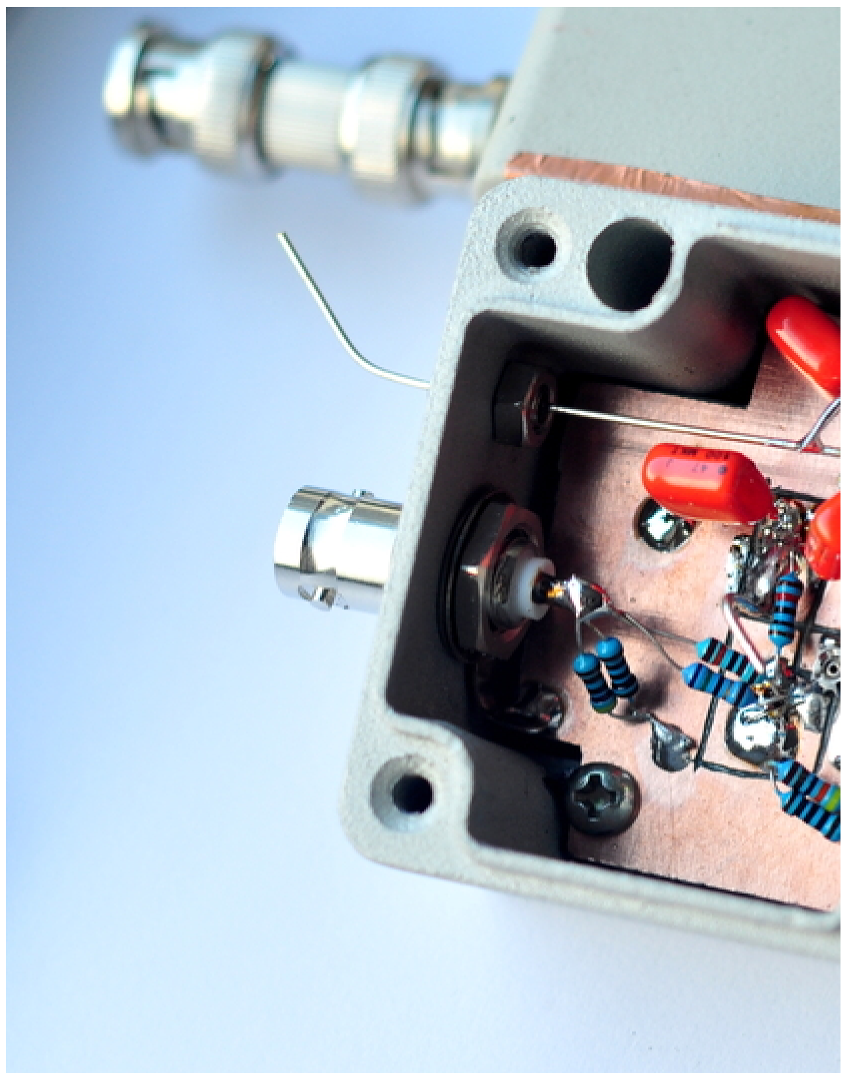
RF Homebrew Instrument >

Power Meter: Calibrator

2013/7/21

Before start building the AD8307 or other Power meter, a calibrator is going to be prepared for them.



Bob Kopski's RF Power calibrator

QEX 2004 Jan/Feb published the Bob Kopski's RF Power calibrator.   very suitable for AD8307, other real RMS Power Meter and SA calibration.

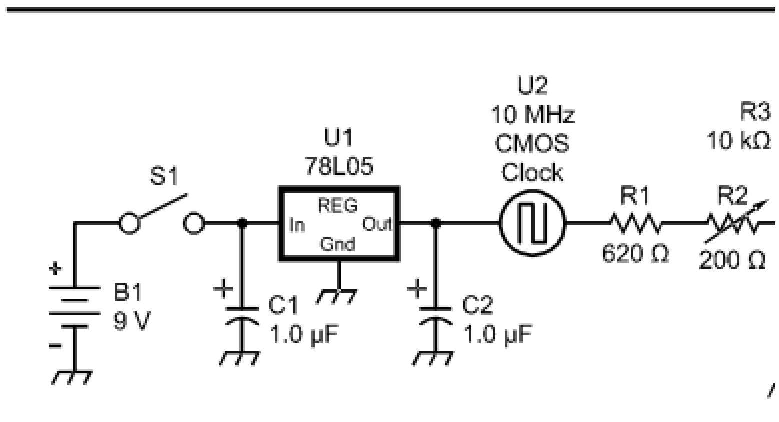


Fig 1—Schematic of the RF power calibrator. Unless othe 5%-tolerance carbon composition or film resistors.

C1, C2—1.0 µF, 35 V tantalum
C3—0.1 µF, ceramic
R1—620 Ω
R2—200 Ω trim pot, Digi Key EVM-36GA00B22 or equivalent
R3—10 kΩ
R4, R6—60.4 Ω, 1/4 W, ±1% film
R5—249 Ω, 1/4 W, ±1% film
U1—5 V regulator, LM78L05
U2—Oscillator, 10 MHz, CTX 045, Digi Key CTX114-ND or equivalent.
Battery, 9 V, alkaline

Battery sn
12BC016 c
Housing, L
desired.
1/4-inch thr
8712 or eq
DPDT slide
1110 or eq
Output cor
Assorted s
board, ass

1) connect a 50R load
2) adjust 200R R2 to get 158mV DC on Test Point
3) AD8307 power meter should show -20dBm
4) true RMS power meter should show -23dBm
5) SA:
fundamental frequency: 10Mhz, -24dBm
50Mhz, -37.9dBm (0.2dB error)
90Mhz, -43dBm (2dB error on this frequency)

Note: none asymmetry by 5% generate only 0.5dB error. This instrument provide about 0.5dB accuracy.

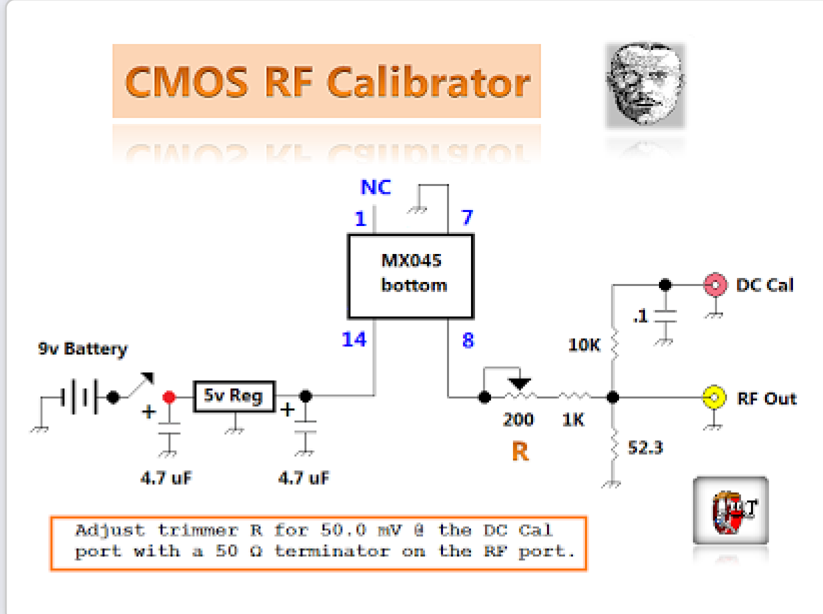
qrp.pops.net version by Jane
Jane build a Bob's calibrator with a little change to the attenuation pad. and also a sinusoid version calibrator.

Contact me

heyongli@gmail.com

G+

go to his excellent website: http://www.qrp.pops.net/RF-workbench-5.asp

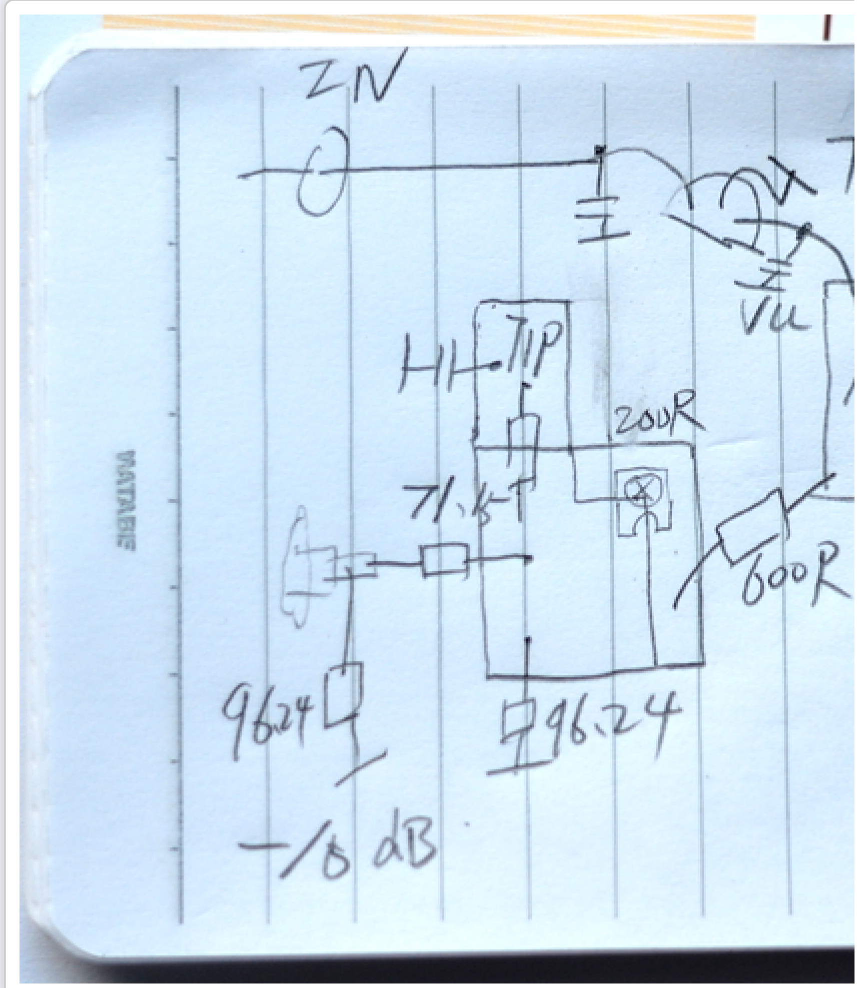


Note again
The recommended CMOS clock oscillator for the CMOS RF calibrator. Digi-Key part # CTX772-ND. Data sheet. which rail-to-rail performance is 0.5V- (Vcc-0.6V), and raise time about 8nS.

Jane also suggestion use -10dBm as calibrator power level. and calibration go on as following step:
1) make a sine wave meter,
2) get same lever as your calibrator.
3) insert a step attenuator to check the linearity.

Calculator： given a test point voltage V in mVolt, what's it's corresponding AD8307 RMS value(NO Attenuator)?
square wave: V*2 Peak to Peak
equivalent sine wave: V*2*2 =4V
AD8307 RMS: 4V/2.83
AD8307 dBm: 10*log[(4V/2.83)^2/50] = 10*log(16*V*V/(2.83*2.83*50*1000)=10*log(V*V/25027.8125

My version of the calibrator



Note:

1) replace 20dB attenuator to 10dB, how get accuracy resistor from 5%: refer to [Attenuator: 50ohm/81dB 1dB step](#)

2) connect a step attenuator is acceptable.

3) I chose a local version CMOS oscillator which similar performance, but raise time ~= 10nS.

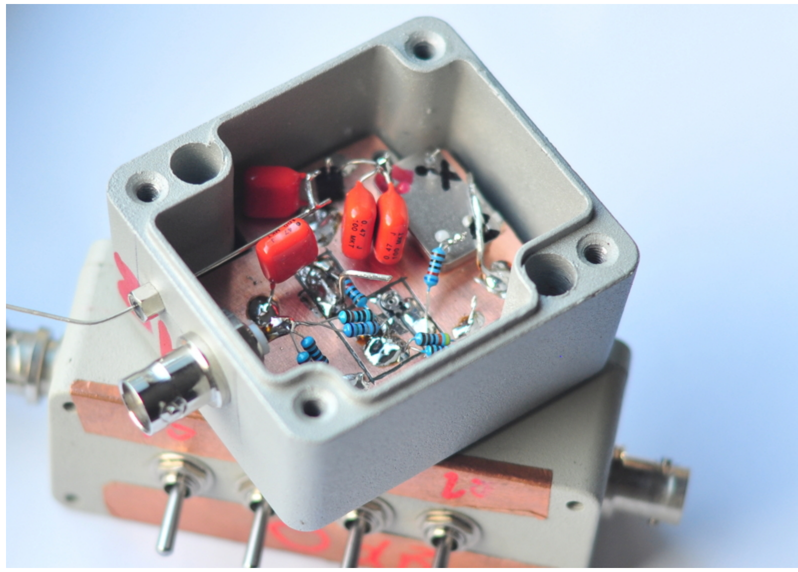
Power Level:

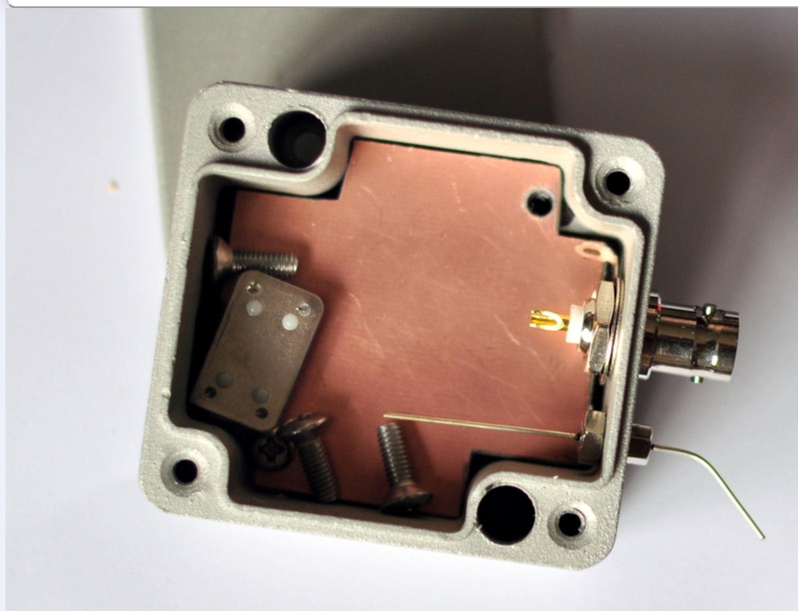
AD8307 power meter should show -10dBm

True RMS power meter should show -13dBm

SA:

- 10Mhz, -14dBm
- 50Mhz, -27.9dBm
- 90Mhz, -23dBm





Comments

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7

New Antenna Array Architectures for Satellite Communications

Miguel A. Salas Natera et al.*
Universidad Politécnica de Madrid, Spain

1. Introduction

Ground stations which integrate the control segment of a satellite mission have as a common feature, the use of large reflector antennas for space communication. Apart from many advantages, large dishes pose a number of impairments regarding their mechanical complexity, low flexibility, and high operation and maintenance costs. hus, reflector antennas are expensive and require the installation of a complex mechanical system to track only one satellite at the same time reducing the efficiency of the segment (Torre et al., 2006).

With the increase of new satellite launches, as well as new satellites and constellation of low earth orbit (LEO), medium earth orbit (MEO), and geostationary earth orbit (GEO), the data download capacity will be saturated for some satellite communication systems and applications. Thus, the feasibility of other antenna technologies must be evaluated to improve the performance of traditional earth stations to serve as the gateway for satellite tracking, telemetry and command (TT&C) operation, payload and payload message or data routing (Tomasic et al., 2002). One alternative is the use of antenna arrays with smaller radiating elements combined with signal processing and beamforming (Godara, 1997).

Main advantages of antenna arrays over large reflectors are the higher flexibility, lower production and maintenance cost, modularity and a more efficient use of the spectrum. Moreover, multi-mission stations can be designed to track different satellites simultaneously by dividing the array in sub-arrays with simultaneous beamforming processes. However, some issues must be considered during the design and implementation of a ground station antenna array: first of all, the architecture (geometry, number of antenna elements) and the beamforming process (optimization criteria, algorithm) must be selected according to the specifications of the system: gain requirements, interference cancellation capabilities, reference signal, complexity, etc. During implementation, deviations will appear as compared to the design due to the manufacturing process: sensor location deviation and sensor gain and phase errors (Martínez & Salas, 2010). In an antenna array, the computation of a close approach of the direction of arrival (DoA) and the correct performance of the beamformer depends on the calibration procedure implemented.

* Andrés García-Aguilar, Jonathan Mora-Cuevas, José-Manuel Fernández González, Pablo Padilla de la Torre, Javier García-Gasco Trujillo, Ramón Martínez Rodríguez-Osorio, Manuel Sierra Pérez, Leandro de Haro Ariet and Manuel Sierra Castañer.
Universidad Politécnica de Madrid, Spain

This chapter is organized with the following sections. Section 2, introduces the relationship between applications and antenna design architectures. Section 3, introduces the new antenna array architectures for satellite communication including motivation and explains experimental examples. Section 4, explains adaptive antenna array and receiver architectures for adaptive antennas systems considering the beamforming with synchronization algorithms. Finally, Section 5 explains the A3TB concept.

2. Applications and antenna design architectures

In recent effort, new antenna array architectures have been under analysis and development. In (Tomasic et al., 2002) a highly effective, multi-function, low cost spherical phased array antenna design that provides hemispherical coverage is analyzed. This kind of novel architecture design, as the geodesic dome phased array antenna (GDPAA) presented in (Tomasic et al., 2002) preserves all the advantages of spherical phased array antennas while the fabrication is based on well-developed, easily manufacturable, and affordable planar array technology (Liu et al., 2006; Tomasic, 1998). This antenna architecture consists of a number of planar phased sub-arrays arranged in an icosahedral geodesic dome configuration.
In contrast to the about 10 *m* diameters dome of the GDPAA, there is the geodesic dome array (GEODA) (Sierra et al., 2007) with 5 *m* diameters dome. This antenna, presented in Fig. 1, has two geometrical structure parts. The first one, is based on a cylinder conformed by 30 triangular planar active arrays, and the second is a half dodecahedron geodesic dome conformed by 30 triangular planar active arrays. The GEODA is specified in a first version for satellite tracking at 1.7 GHz, including multi-mission and multi-beam scenarios (Martínez & Salas, 2010). Subsequently, the system of the GEODA has been upgraded also for transmission (Arias et al., 2010).

a b c

Fig. 1. a) The GEODA, b) The active sub-array demonstration, and c) The 45 elements planar active sub-array.

The antenna arrays technology in the user segment for satellite communications will substitute reflectors providing a more compact and easy to install antenna system, which is an interesting solution e.g. for satellite on the move (SOTM) system. There is a great diversity of solutions for fixed and mobile satellite communication systems including a large number of applications. Inmarsat broadband global area network (Inmarsat-BGAN) (Franchi et al., 2000) is the most representative example among mobile satellite systems (MSS), which gives land, maritime and aeronautical high speed voice and data services with global coverage using GEO satellites at L-band.

MSS services are divided into two groups, those that offer a regional coverage usually with GEO satellites, and those which offer a global coverage based on LEO or MEO satellite constellations. Depending on the coverage, there are some examples for MSS with regional coverage as the mobile satellite system (MSAT) in EEUU, Canada and South America, Optus in Australia, N-Star in Japan, Asia cellular satellite (ACeS) in Asia or Thuraya in the Middle East and in the North of Africa. While for MSS of global coverage there are some examples as Iridium, ICO Global Communications, Globalstar, Teledesic, etc. (Evans, 2009; Wu, 1994). Most of the MSSs work at L and S band, new applications on satellite to mobile terminal links work at X, Ku and Ka band, and satellite to base station connections work at L, S and C band. A number of applications is broad and lead terrestrial telecommunications market to offer a wider coverage: high speed voice and data (internet access, SMS, VoIP), digital video broadcasting by satellite 2 (DVB-S2) and digital video broadcasting satellite services to handhelds (DVB-SH), global position system (GPS) and Galileo, security, control and machinery monitoring on ships and aircrafts, teleeducation or telemedicine.

These modern satellite communications systems require new antenna solutions for base stations, aeronautical applications or personal communications services (PCS) on-the-move (Fujimoto & James, 2001). Within these applications, antenna array systems are potentially the best choice due to, as discussed above, its capability to perform electronically steering or beamforming, increase the antenna gain, and conform over curved or multifaceted surfaces the radiating elements. Portable antennas for PCS must be easy to install and mechanically robust, besides compact and lightweight (García et al., 2010) as the antenna array presented in Fig. 4.a. The design of antenna systems to provide high data rates for reliable PCS boarded on ships is not so strict in term of the geometrical requirements because it does not have space limitations (Geissler et al., 2010). However, in the case of land or airborne vehicles, geometrical and mechanical constraints are more severe. Antennas for terrestrial vehicles must be low profile, and for airborne vehicles aerodynamic shapes must be considered (Baggen et al., 2007; Vaccaro et al., 2010). Moreover, for the civil market conformal antenna arrays (Schippers, 2008; Kanno et al., 1996), or multi-surface arrays (Khalifa & Vaughan, 2007) are suitable choices to deal with the system aesthetic partiality.

Technological challenges have been faced during the implementation of satellite communication systems in the last decades. The design of a Test-Bed flexible and modular for testing or debugging beamforming algorithms and receiver architectures is an invaluable contribution in the educational, research and development area on satellite communication systems. The adaptive antenna array Test-Bed (A3TB) concept is based on the use of antenna arrays with beamforming capability to receive signals from LEO satellites (Salas et al., 2008). The scope of the A3TB is to probe the concept of antenna arrays applied to ground stations instead of reflectors for different applications, such as telemetry data downloading. It is also a good chance for Universities and Research Centers aiming to have their own ground station sited in their installations.

The A3TB ground station relies on the use of an antenna array to smartly combine the received signals from the satellite thanks to the implementation based on software defined radio (SDR) technology. The advantages of the SDR implementation is that A3TB architecture can be used to process any received signal from LEO satellites in the band imposed by the radio frequency (RF) circuits. Moreover, most of the processing is performed in software, so that appropriate routines can be used to process any received signal. The A3TB can be used to analyze the feasibility of different receivers and beamformer

algorithms, regarding the capability to switch the receiver architecture in terms of the synchronizer algorithm configuration (Salas et al., 2007).
The current version has been developed to track The National Oceanic and Atmospheric Administration (NOAA) satellites in the very high frequency (VHF) band, in particular, the automated picture transmission (APT) channel (Salas et al., 2008). Previous versions of A3TB dealt with low rate picture transmission (LRPT) signals from the meteorological operational satellite-A (MetOp-A), where a complete receiver with beamforming and synchronization stages has been implemented (Salas et al., 2007; Martínez et al., 2007).

3. Antenna arrays for satellite communications

Satellite applications require compactness, lightweight and low cost antenna systems to be mounted on a terrestrial vehicle, an aircraft or a ship, or as a portable man-pack or a handset, and to be competitive against ground systems. Its major advantage is the possibility of getting a wider or even a global coverage. For such purposes, antenna arrays offer the technology to get a directive system whose steering direction can be electronically and/or mechanically controlled. However, planar arrays usually cannot steer more than 60º-70º from the normal direction of the antenna (Mailloux, 2005). Thus, when a wider angular coverage is required conformal arrays are an appropriate option (Josefsson & Persson, 2006). Arrays can approximate conformal shapes, such as spheres or cylinders, using several planar arrays, simplifying fabrication of active components (Sierra et al., 2007).
Since the low cost and low weight specifications are of importance, micro-strip antennas are mostly used, due to its capacity to be printed over a dielectric substrate with photolithography techniques. Low cost and low permittivity substrates are usually used such as FR4 or PTFE with different quantities of glass or ceramic impurities. For more demanding applications, ceramics, like alumina or high/low temperature co-fired ceramics (HTCC/LTTC) allow the use of smaller components thanks to its high permittivity, and give robustness against mechanical stresses and high temperatures.

3.1 Geodesic antenna array for satellite tracking in ground station

The aim of using a single antenna for tracking many satellites at the same time avoiding mechanical movements as well as its inexpensive cost make these antennas an alternative to be considered (Salas et al., 2008). Multi-beam ability and interference rejection are facilitated thanks to the electronic control system of such antennas that improves the versatility of the ground stations.
The GEODA is a conformal adaptive antenna array designed for MetOp satellite communications with specifications shown in Table 1. This antenna was conceived to receive signals in single circular polarization (Montesinos et al., 2009). Subsequently, in recent efforts the system has been upgraded also for transmission and double circular polarization (Arias et al., 2010). Hence, operating at 1.7 GHz with double circular polarization it can communicate with several LEO satellites at once in Downlink and Uplink. Current structure is the result of a comprehensive study that valued the ability to cover a given spatial range considering conformal shape surface and a given beamwidth (Montesinos et al., 2009). As Fig. 1 shows, GEODA structure consists of a hemispherical dome placed on a cylinder of 1.5 meters height. Both cylinder and dome are conformed by 30 similar triangular planar arrays (panels). Each panel consists of 15 sub-arrays of 3 elements (cells). The radiating element consists of 2 stacked circular patches with their own

RF circuits. The principal patch is fed in quadrature in 2 points separated 90º in order to obtain circular polarization. The upper coupled patch is used in the aim of improving the bandwidth.
Each panel is able to work itself as an antenna since they have a complete receiver that drives the 1.7 GHz signal to an analog to digital converter (ADC). In order to adapt the signal power to the ADC, it is mandatory to implement a complete intermediate frequency (IF) receiver consisting of heterodyne receiver with an automatic gain control block. Hence, each triangular array has active pointing direction control and leads the signal to a digital receiver through an RF conversion and filtering process. To follow the signal from the satellite, the main beam direction has to be able to sweep an angle of 60º. In this way, it is needed a phase shift in the feeding currents of the single radiating element. Previous calculations have demonstrated that 6 steps of 60 degrees are needed to achieve the required sweeping angle. An adaptive digital system allows the adequate signal combination from several triangular antennas. The control system is explained in (Salas et al., 2010).

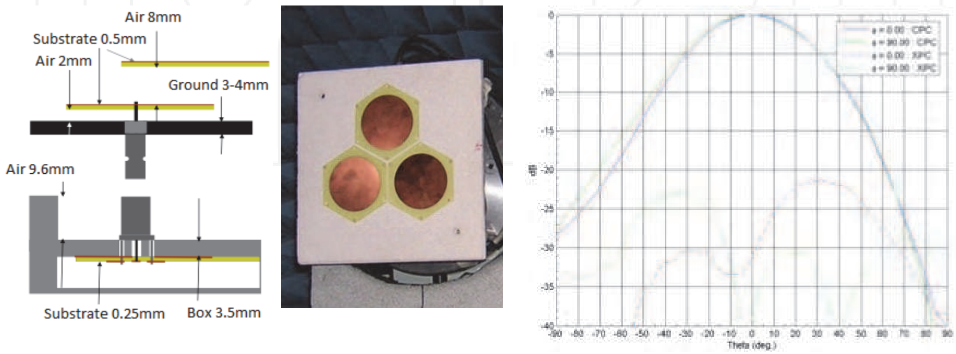
Parameter	Specification	Parameter	Specification
Frequency range [GHz] **Tx:** **Rx:**	 1.65 to 1.75 1.65 to 1.75	**Isolation between Tx and Rx [dB]**	>20
Polarization	Dual circular for Tx and Rx bands	**VSWR**	1.2:1
G/T [dB/K] **For elevation >30º** **For elevation 5º**	 3 6	**SLL [dB]**	-11
EIRP [dBW]	36	**Size [m]**	1.5x1.5x3
3dB beamwidth [deg.]	5	**Accuracy steering [deg.]**	±1.4
Maximum gain [dBi]	29	**Coverage [deg.]:** **Azimuth** **Elevation**	 360º >5º
Efficiency [%]	50		

Table 1. Main specifications for GEODA antenna.

3.1.1 Cell radiation pattern

Based on the study presented in (Sierra et al., 2007), the single radiating element is a double stacked circular patch that works at 1.7 GHz with 100 MHz bandwidth. In order to obtain circular polarization, the lower patch, which has 90 mm diameter, is fed by 2 coaxial cables in quadrature. Both coaxial cables connect the patch with a hybrid coupler to transmit and

receive signals with both, right and left, circular polarizations. The upper patch is a circular plate with 78.8 mm diameter, and it is coupled to the lower patch increasing the bandwidth by overlapping both resonant frequencies tuning the substrate thickness and the patch diameter size. Fig. 2.a shows the radiating element scheme and main features of the layer structure are specified in (Montesinos et al., 2009).
A cell sub-array of 3 radiating elements shown in Fig. 2.b is considered the basic module to build the planar triangular arrays. The whole cell fulfills radiation requirements since it has a good polar to crosspolar ratio and a very low axial ratio. Likewise, as it is presented in Fig. 2.c, the radiation pattern shows symmetry and low side lobes for full azimuth.



a b c

Fig. 2. a) Assembly of the single radiating element, b) Cell scheme, and c) Cell radiation pattern.

3.1.2 Transmission and Reception (T/R) module and cell distribution

Different T/R module configurations have been considered, providing either single or double polarization (Arias et al., 2010). T/R module allows amplifying and controlling the phase shift between signals, received and transmitted, providing an adaptive beam and steering direction controller in the whole working pointing range. As Fig. 3 shows, the design implemented contains a hybrid coupler, enabling double circular polarization; a double pole double throw (DPDT) switch, selecting polarization associated with transmission and reception way; 2 low noise amplifiers (LNAs), which amplify the signal received or transmitted; a single pole double throw (SPDT) switch, choosing transmission or reception way; and phase shifters, introducing multiples of 22.5º relative shift phases to form the desired beam. These surface mount devices have been chosen in order to reduce space and simplify the design.
Signals transmitted/received by the 3 T/R modules placed in a cell are divided/combined thanks to a divider/combiner circuit composed of 3 hybrid couplers that leads the signal to a general T/R module where signal is amplified. Due to transmission and reception duality, 2 SPDT switches are used to select the amplification way. Furthermore, each T/R module has associated a -25dB directional coupler that is used to test T/R modules in the transmission mode. Additionally, reception mode is tested by measuring signal in the divider/combiner circuit. A single pole 6 throw (SP6T) switch selects the path that is tested.

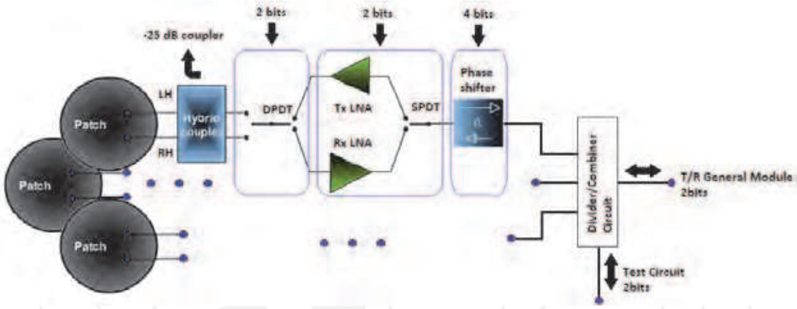


Fig. 3. Cell sub-array and RF circuit.

3.1.3 Control system

The control system has two main parts (Salas et al., 2010), the hardware structure and the control software. The two level hardware structure has the lowest possible number of elements, making the control simpler in contrast to the previous in (Salas et al., 2010). Finally, an inter-integrated circuit (I2C) expander is used to govern T/R modules individually, and one more cover cell needs (LNA of call and test). A multipoint serial standard RS-485 is used to connect the computer with the panels.

3.2 Portable antenna for personal satellite services

New fix and mobile satellite systems (Evans, 2000) require antenna systems which can be portable, low profile and low weight. Planar antennas are perfect candidates to fulfill these specifications. Usually slots (Sierra-Castañer et al., 2005) and printed elements (García et al., 2010) are most used as radiating elements.

3.2.1 Antenna system structure

In this subsection it is introduced a printed antenna for personal satellite communications at X band, in Fig. 4. Table 2 shows main antenna characteristics.

Parameter	Specification	Parameter	Specification
Frequency range[GHz] **Tx:** **Rx:**	 7.9 to 8.4 7.25 to 7.75	**Efficiency [%]**	50
Polarization	Dual circular polarization for Tx and Rx bands	**Isolation between Tx and Rx [dB]**	>17
G/T [dB/K]	7	**VSWR**	1.4:1
EIRP [dBW]	32	**SLL [dB]**	-11
3dB beamwidth [deg.]	5	**Size [m]**	40x40x2.5
Maximum gain [dBi]	25	**Weight [Kg]**	2

Table 2. Portable antenna specifications.

This is a planar, compact, modular, low loss and dual circular polarized antenna, for Tx and Rx bands, simultaneously. It is made up by a square planar array of 16x16 double stacked micro-strip patches, fed by two coaxial probes. A hybrid circuit allows the dual circular polarization (Garg et al., 2001). Elements are divided in 16 sub-arrays excited by a global power distribution network of very low losses, minimizing the losses due to the feeding network and maximizing the antenna efficiency. In order to reduce side lobe levels (SLL), the signal distribution decreases from the centre to the antenna edges, keeping symmetry with respect to the main antenna axes. The antenna works at X band from 7.25 up to 8.4 GHz with a 14.7% relative bandwidth for a 1.4:1 VSWR and a maximum gain of 25 dBi.

3.2.2 Sub-array configuration

The sub-array configuration can be seen in Fig. 4.a. It makes possible to separate the fabrication of these sub-arrays from the global distribution network, simplifying the corporative network and getting a modular structure suitable for a serial fabrication process. Each sub-array is a unique multilayer board, where PTFE-Glass substrate of very low losses has been used as base material. The power distribution network is connected to each sub-array through (SMP-type) coaxial connectors.

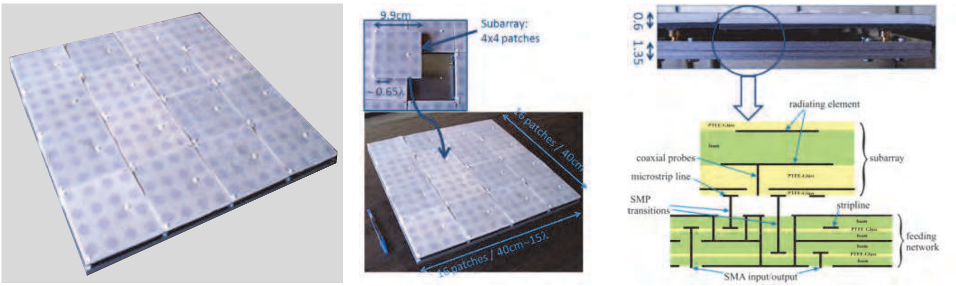


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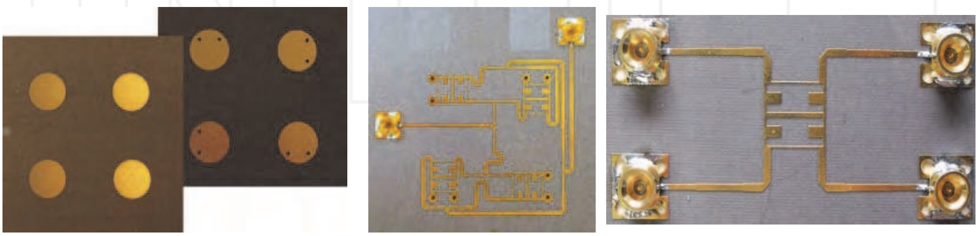
Fig. 4. a) Dual polarized portable printed antenna for satellite communication at X band, b) Sub-array perspective view, and c) Side view and multilayer scheme.

Fig. 5.a and Fig. 5.b show the sub-array unit cell. In order to obtain better polarization purity, each element is rotated 90º and excited by a 90º phase-shifted signal. Moreover, in Fig. 5.c is showed a miniaturized branch-line coupler (BLC) of three branches working as a wide band hybrid circuit (García et al., 2010; Tang & Chen, 2007).



a b c

Fig. 5. Unit cell test board, a) Unit cell test board 2x2 stacked patches, b) Micro-strip feeding network, and c) Miniaturized BLC Prototype.

A conventional configuration takes up an area of 13.3 cm^2 which is big compared to the radiating element and the sub-array subsystem size. Therefore, a miniaturization of the BLC is needed using the equivalence between a $\lambda/4$ transmission line and a line with an open-ended shunt stub. An area reduction about 35% is achieved and the hybrid circuit behaves like a conventional BLC. In Fig. 6.b and Fig. 6.c measurement results for the BLC in Fig. 5.c are shown compared with simulations.
Fig. 7 depicts some sub-array measurements. The copular to crosspolar ratio is better than 25 dB and axial ratio is under 0.9 dB in the whole bandwidth.

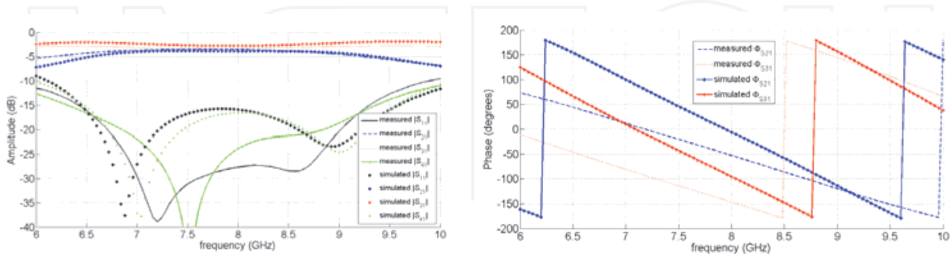


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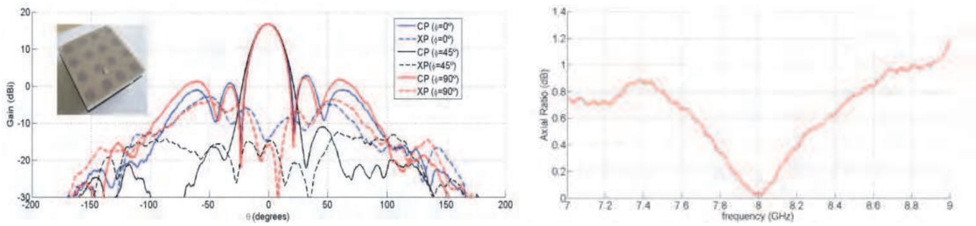
Fig. 6. Miniaturized BLC, Measured and simulated S-parameters in: a) Amplitude, and b) Phase.



a b

Fig. 7. 4x4 patch sub-array measurements, a) Radiation pattern at 7.75 GHz, and c) Axial ratio for right-handed circular polarization.

3.2.3 Low losses power distribution network

The global feeding network presented in Fig. 8.a is a protected strip-line, where foam sheets of high thickness are used to get low losses. Such a kind of feeding network allows keeping a trade-off between the simplicity of exciting the radiating elements using printed circuits and the loss reduction when the distribution network is separated in a designed structure to have low losses. Losses in the structure are around 0.6 dB/m which yields to 0.3 dB of losses in the line. Two global inputs/outputs using SMA-type connectors, one for each polarization, excite the strip-line networks.
Vertical transitions have to be treated carefully and must be protected to avoid undesired higher order mode excitation. Thereby, it has been design a short-ended pseudo-waveguide, adding some extra losses about 0.3 dB, for two kinds of vertical transitions, as can be seen in Fig. 8.b and Fig. 8.c.

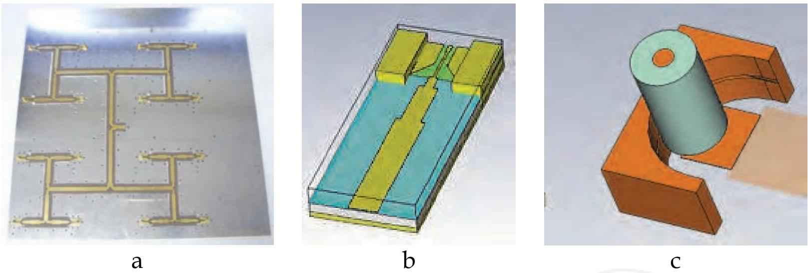


Fig. 8. a) Protected strip-line global corporative network for one polarization, b) Transitions from strip-line to SMA-type connector, and c) Transitions from strip-line to SMP-type connector.

3.2.4 Antenna performance

Fig. 9 depicts measured radiation pattern at 7.75 GHz, gain and axial ratio for the antenna system. It is shown a maximum gain of 25 dBi in the lower band and about 22 dBi in the upper band, and a SLL around 11 dB. Copolar to crosspolar ratio is better than 30 dB and axial ratio is under 0.7 dB. Total losses are about 4 dB in the working band.

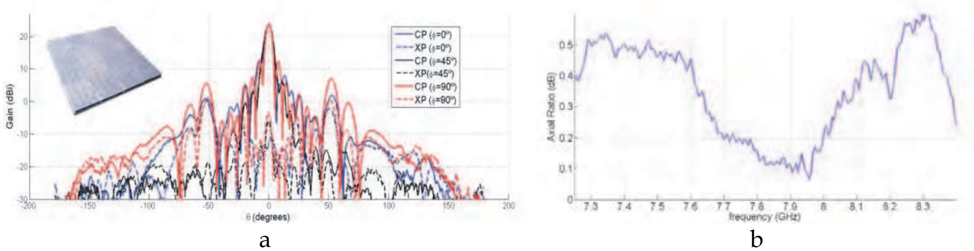


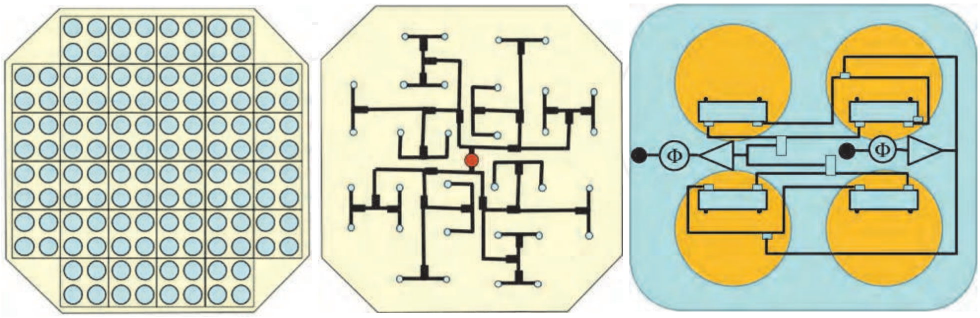
Fig. 9. Antenna measurements results, a) Radiation pattern at 7.75 GHz, and c) Axial ratio for right-handed circular polarization.

3.3 Electronically steerable antennas for mobile and fixed portable systems

At present, two types of electric steerable antenna systems can be used to access the satellite communication services (Bialkwoski et al., 1996). These are: fixed position portable systems and mobile systems such as those installed on a land vehicle. The fixed portable antenna system is relatively easy to be accomplished by the antenna designer. The design involves standard procedures that concern the operational bandwidth, polarization and moderate gain (García et al., 2010). One drawback of the fixed position portable system is that they require the user to be stationary with respect to the ground. This inconvenience can be overcome with the mobile antenna system. A mobile user complicates the scenario since the ground mobile antenna needs to track the satellite (Alonso et al., 1996). The design of such a system is more challenging as new features associated with the mobility of the system have to be incorporated (Fernández et al., 2009). The requirement leads to a narrow beamwidth, for which satellite tracking is required as the vehicle moves around. Electronically steerable antennas enable the development of reconfigurable antennas for satellite applications.

3.3.1 Steerable antenna for fixed position portable systems

This antenna is a fixed satellite communication system with high gain at X band, consisting of an antenna array that integrates 32 2x2 sub-array modules in the complete antenna, as shown in Fig. 10.a. It is a planar and dual circular polarized antenna for Tx and Rx bands simultaneously. It is made up by a planar array of double stacked circular micro-strip patches, fed by 2 coaxial probes to generate circular polarization. A hybrid circuit allows the dual circular polarization as shown in Fig. 10.b.



a b c

Fig. 10. Active multi-beam antenna, a) Top view, b) Feeding network of the complete antenna, and c) Beamforming network of the 2x2 sub-array module

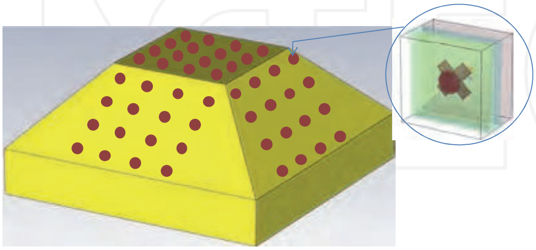
The antenna has the same design parameters, structure and configuration as the antenna explained in Section 3.2 but with a different feeding network, as previously shown. In this case, the beamforming network requires changes in the feeding phase in the 2x2 sub-arrays, which can be achieved by phase shifters (ϕ) associated with different sub-arrays (Fig. 10.c). All these sub-arrays are connected to a feeding network, in Fig. 10.b, formed by transmission lines with low losses in strip-line. General specifications of the steerable antenna for fixed position portable systems are provided in Table 3.(a).

3.3.2 Automatic steerable antenna for mobile systems

A broadband circularly polarized antenna for satellite communication in X band is presented in Fig. 11 and specified in Table 3.(b). The arrangement features and compactness are required for highly integrated antenna arrays. It is desired to get a low-gain antenna for mobile satellite communications with low speed of transmission. In this system, the antennas are formed by 5 planar 4x4 arrays of antennas, which form a truncated pyramid with a pointing capability in a wide angular range, so that among the 5 planar arrays the complete antenna can cover any of the relative positions between the mobile system and the satellite in a practical way. The scheme of the active antenna can be seen in Fig. 11.

As it can be observed in Fig. 11.a, the antenna terminal is a multi-beam printed antenna shaped as a trunk pyramid capable of directing a main beam in the direction of the satellite. The antenna steering system consists of a multi-beam feeding structure with switches that lets combine the feed of each 4x4 arrays to form multiple beams. Switching the different 4x4 arrays, it is achieved different multiple beams and the variation of the steering direction.

The complete antenna consists of a Tx and Rx module that works independently in the 2 frequency bands.
The antenna has multiple beams covering the entire space to capture the satellite signal without moving the antenna. The signal detected in each of the beams is connected to a switch, which, by comparison, is chosen the most appropriate 4x4 array. The steering direction of the 4x4 array can vary between a range of directions that covers a cone angle range of 90º. To obtain the required gain and cover the indicated range, it is required around 15 beams, which can be obtained by integrating the beamforming networks with switches in the design as presented in (Fernández et al., 2009).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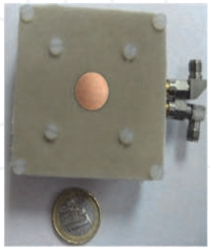

b

Fig. 11. Complete antenna structure, a) Radiating element of the 4x4 arrays, and b) Prototype top view.

The radiating element of the 4x4 array is one 2 crossed dipoles with a stacked circular patch as shown in Fig. 11.a and Fig. 11.b. In Fig. 12 the cross-section of the radiating element structure is presented.

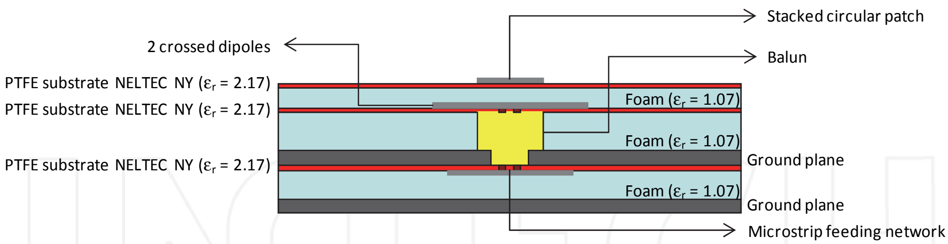


Fig. 12. Cross-section scheme of the radiating element.

The key element of the radiating element feeding structure (Fig. 14.b) is a resonant micro-strip feed ring that has been implemented, as well as a micro-strip 90º branch-line coupler to obtain the desired right hand or left hand circular polarizations (RHCP or LHCP) which ensures adequate port coupling isolation. The S-parameters in amplitude and phase of the micro-strip feeding structure are shown in Fig. 13.a and Fig. 13.b.
Fig. 14.a depicts the S-parameters of the radiating element with the micro-strip feed structure and they fulfill the specification, in Table 3.(b). In Fig. 14.c, the radiation pattern of the radiating element at 7.825 GHz is shown and in Fig. 14.d the radiation pattern of the 4x4

arrays is presented. It is shown a maximum gain of 19.4 dBi at the center frequency band (7.825 GHz). Copolar (CP) to crosspolar (XP) ratio is better than 17 dB and the axial ratio is under -3dB.

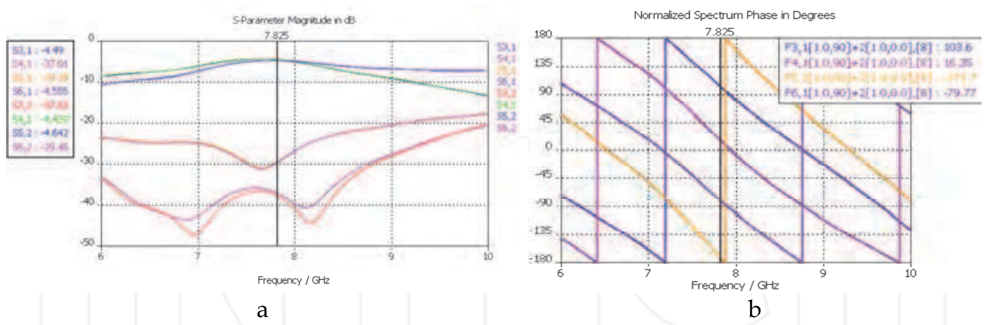


Fig. 13. Micro-strip feeding structure, a) Amplitude of S-parameters, and b) Phase of S-parameters.

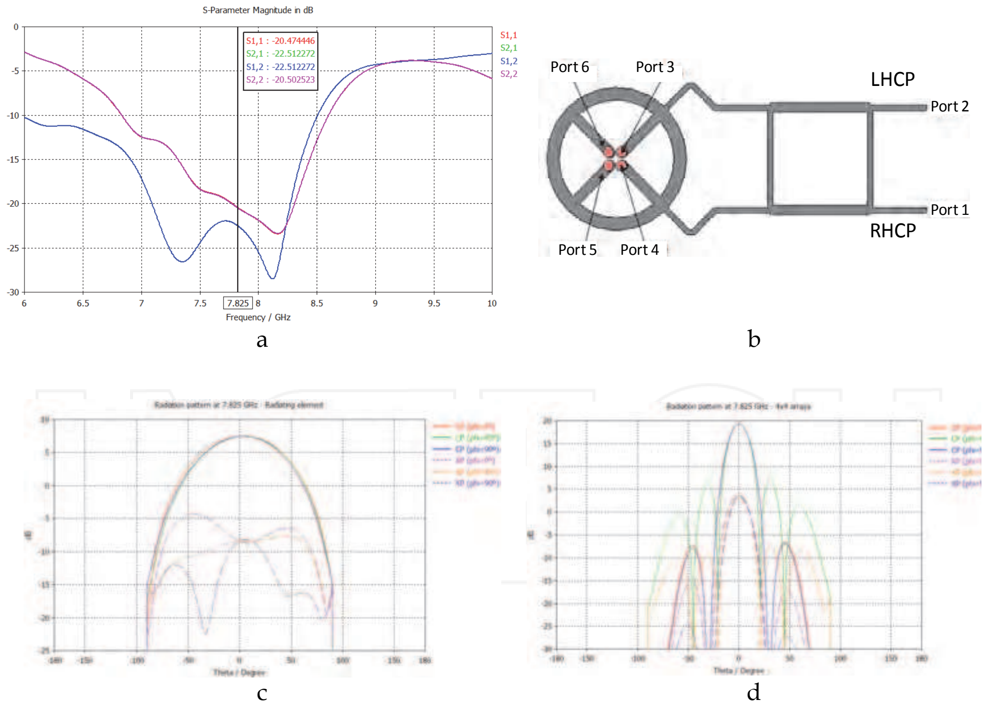


Fig. 14. a) S-parameters, b) Resonant ring + 90° branch-line coupler, c) radiation pattern at 7.825 GHz, and d) 4x4 array radiation pattern.

Parameter	Value (a)	Value (b)	Comments
Freq. range [GHz] Rx **Tx**	7.25 - 7.75 7.9 - 8.4	7.25 - 7.75 7.9 - 8.4	Microwave applications.
G/T (in Rx) [dB/K]	7	7	
EIRP (in Tx) [dBW]	32	32	
Beamwidth at -3dB [deg.]	4	20	
Polarization	circular	circular	In both, reception and transmission.
Gain [dBi]	>28	>15	
Axial ratio [dB]	< 1	<3	**(a)** Between ±50°. **(b)** Between ±45°.
VSWR	< 1.4:1 (-15.6 dB)	< 1.5:1 (-13.9 dB)	
Isolation between ports [dB]	< -17	< -15	
Radiation pattern [deg.]	±35	±90	Steering direction tilt.
Dimensions [cm]	40x40x4	20x20x15	

Table 3. (a) General specifications of the steerable antenna for fixed position portable systems , and (b) General features of the automatic steerable antenna for mobile systems.

3.4 Transmit-array-type lens antenna for terrestrial and on board receivers

Technology in satellite communications has revealed an increasing interest in novel smart antenna designs. Phased-array based designs are basic in electronically reconfigurable devices for satellite applications, which are more and more demanding. The strict requirements in terms of architecture, shape and robustness are important constraints for the development of planar lens-type devices. Regarding the usage and location, lens-type devices are useful for either terrestrial or on board receivers, in vehicular technology. Some clear examples are satellite communications for aircrafts preserving the fuselage aerodynamics or for some other kind of vehicles such as trains, etc.

3.4.1 Introduction to lens-type structures

In a general view, in lens-type a particular signal is received (in our case, an electromagnetic wave with specific features in terms of frequency, wave-front, etc.), it is processed (either complex signal processing techniques or only phase correction tasks can be considered in this interface), and finally, the processed signal is retransmitted.

Regarding the lens configuration, a transmit-array lens consists of three well distinguished interfaces: the first one for signal reception, one interface for signal processing, and the last one for processed signal re-radiation, as depicted in Fig. 15.

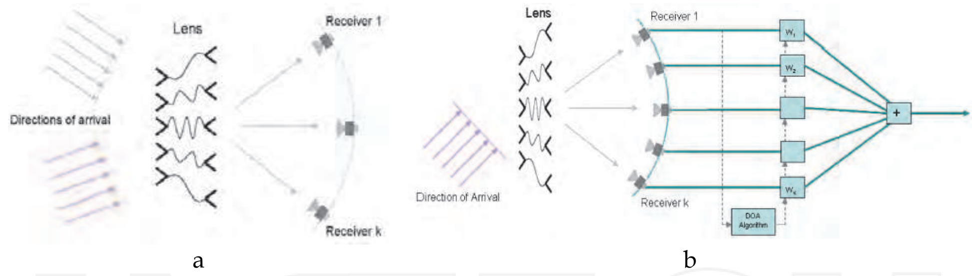


Fig. 15. a) Multi-user scheme with different receivers and transmitters, and b) Adaptive scheme with DoA determination.

These structures are intimately related to reflect-array ones, where the reception and transmission interfaces are turned to be the same interface, with a reflection-type behavior (Encinar & Zornoza, 2001). Although in an equal output phase configuration a transmit-array device behavior would be similar to the one obtained with a reflect-array, the transmit-array offers the advantage of removing the feed blockage.

In a transmission scheme, depending on the transmitter position regarding the lens, a different steering direction is achieved and a different user is pointed. In the case of reception, the situation is the same: the user position configures the direction of arrival, which determines the receiver position around the lens (Padilla et al., 2010a). In adaptive schemes, applying the proper processing algorithm to the signal received in the different receivers around the lens, it is possible to develop an adaptive steering vector, in terms of the desired direction of arrival.

3.4.2 Transmit-array lens architecture and design

Lens-type structures provide two fundamental advantages. First, phase error correction due to spherical wave front coming from the feeding antenna. Fig. 16.a shows this effect. Second, new radiation patterns configuration. Fig. 16.b depicts this fact.

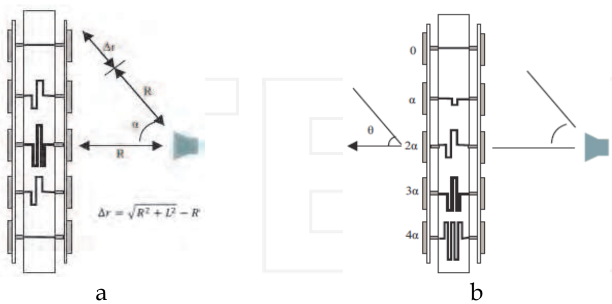
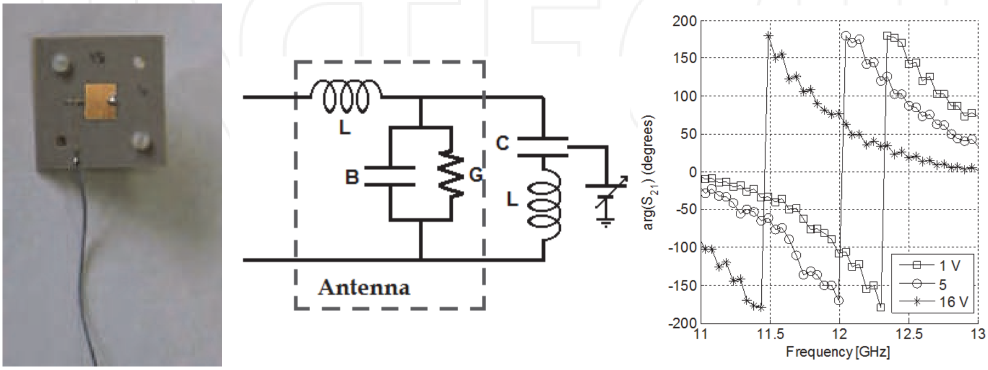


Fig. 16. a) Phase error correction, and b) Radiation pattern reconfiguration.

3.4.3 Electronically reconfigurable devices for active transmit-array lenses

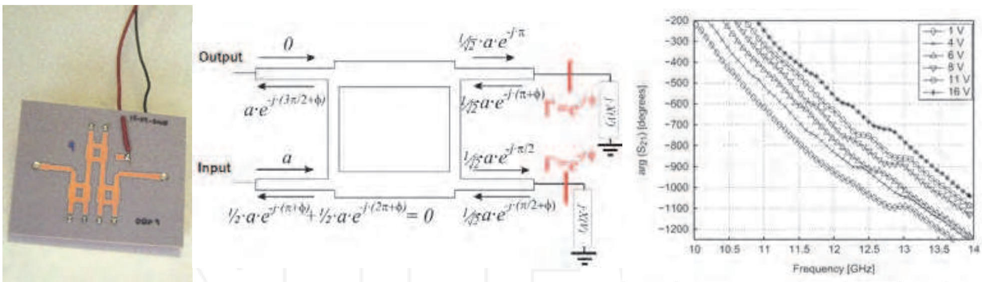
The addition of reconfigurability on transmit-array devices requires the possibility of controlling the phase response of the transmitted signal at each cell of the lens. Electronic control of phase signal may be added in two different ways: First, electronic tuning of the

radiating element phase response (Padilla et al., 2010a): Modifications in the radiating element circuital behavior lead to changes in phase response (arg[S_{21}]). Fig. 17 shows an electronically reconfigurable microwave patch antenna for this purpose, along with the equivalent circuit and prototype outcomes in terms of phase.
Second, electronic tuning of phase shifters in transmission lines (Padilla et al., 2010c): Modifications in the phase response of the phase shifters lead to corresponding changes in phase response. Some options are applied for these devices, such as hybrid couplers, etc. Fig. 18 shows a microwave phase shifter prototype for this purpose, along with the working scheme and its outcomes in phase.



a b c

Fig. 17. Electronically reconfigurable antenna, a) Patch antenna prototypes, b) Equivalent circuit, and c) Phase behavior in frequency.



a b c

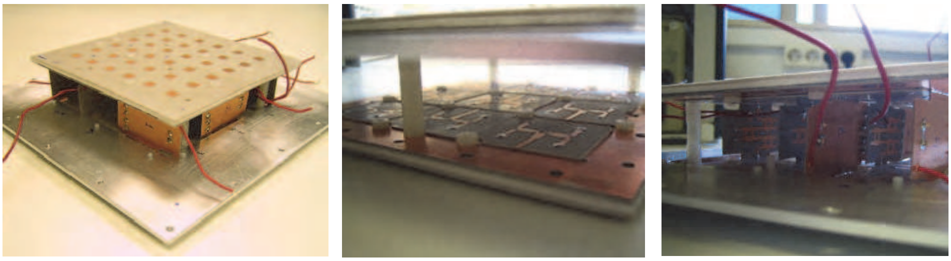
Fig. 18. Electronically reconfigurable phase shifter, a) Phase shifter prototype, b) Working scheme, and c) Phase behavior in frequency.

3.4.4 Electronically reconfigurable active transmit-array prototype

One electronically reconfigurable prototype is presented in Fig. 19 and detailed in this section. The prototype design implies the use of microwave phase shifters according to the design specified in section 3.4.3. This transmit-array lens prototype operates at 12 GHz. Main specifications are provided in Table 4.

Parameter	Value	Comments
Frequency range [GHz]	12 ± 0.5	Microwave applications.
Polarization	Linear	In both, reception and transmission.
Directivity [dBi]	>21	
Axial ratio [dB]	< 1	Between ±50º elevation.
S_{11} [dB]	< -20	
Radiation pattern [deg.]	±30	Steering direction tilt, for both H and V planes.
Feeding antenna [mm]	120	Corrugated horn linearly polarized
Phase shifters [deg.]	360	Full phase range variation.
Transmit-array elements	36	6x6 array topology.
Separation between elements	$0.7\lambda_0$	Related to the wavelength

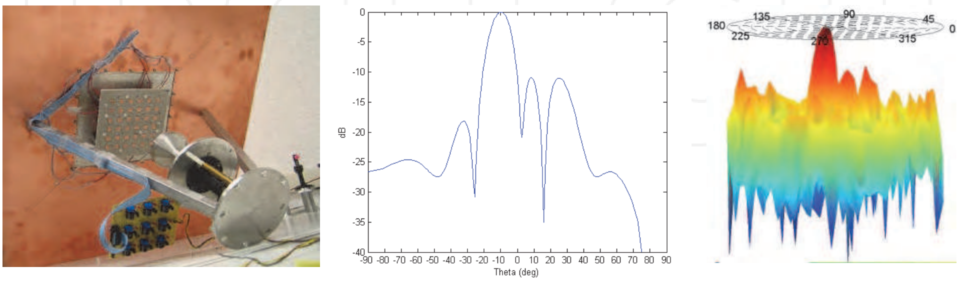
Table 4. Main features of the electronically reconfigurable transmit-array prototype.



a b c

Fig. 19. Transmit-array core, a) Transmit-array prototype, b) Distribution networks, and c) Phase shifter integration.

The electronically controllable steering capabilities are tested and assured for a range of ± 30ºin each main axis. An example of radiation pattern is provided in Fig. 20, for 9º tilt in one of the main axes.



a b c

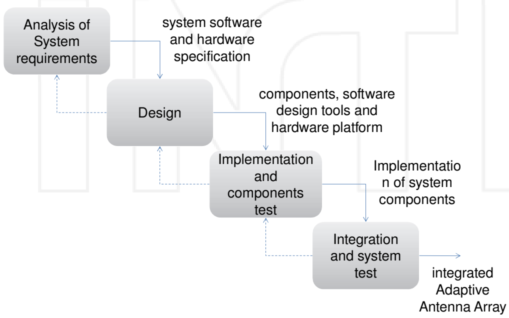
Fig. 20. a) Complete transmit-array with feeder and control circuits; and transmit-array measurement results for 9º tilt in one axis, b) H plane, and c) 3D plot.

4. Adaptive antenna array

Adaptive antennas can be described as systems usually based on three main parts: the antenna array, the receiver architecture and the beamforming scheme. Thus, adaptive antennas have those advantages owing to those three main parts. The system capabilities increase as complexity and development cost do. Furthermore, since signal processing is the basement of the adaptive antenna concept it is important to analyze the design challenges in terms of hardware architecture and components such as processors and embedded systems.
The antenna array provides the capability of performing the antenna pattern meeting the environment requirement under study. Besides, receiver architectures have some interesting advantages depending on the implemented receiver arraying technique such as signal to noise ratio (SNR) and bit error rate (BER) performance enhancement. Furthermore, symbol synchronization and carrier recovery can be used increasing the receiver complexity but providing higher performances. Finally, beamforming schemes use multiple antennas in order to maximize the strength of the signals being sent and received while eliminating, or at least reducing, interference as discussed in Section 4.3.
Adaptive antenna arrays are often called Smart Antennas because they have some key benefits over traditional antennas, by adjusting traffic patterns, space diversity or using multiple access techniques. The main four key benefits are: First, enhanced coverage through range extension by increasing the gain and steering capability of the ground station antenna; Second, enhanced signal quality through multi-target capability and reduction of interferences; finally, adaptive antennas improve the data download capacity in the ground segment of satellite communication by increasing the coverage range (Martínez et al., 2007).

4.1 Design and architecture based on software defined radio

For design there is the well known waterfall life cyclic model (Royce, 1970) that can be used to manage main aspects of the design of architectures. Thus, some tasks must be fulfilled subsequently as follow in Fig. 21.a.
Fig. 21.b shows the design schemes resulting of the requirement analysis stage corresponding software and hardware system specifications. In the depicted scheme, there are some system components such as the radiating element and RF circuits that are often designed under iterative prototyping model.



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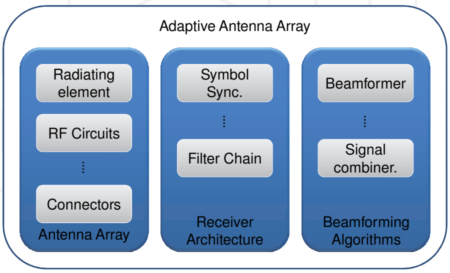


b

Fig. 21. a) Water life cyclic model of the adaptive antenna array design, and b) Simplified design scheme of adaptive antenna arrays.

Regarding the hardware implementation, tables presented in (Martínez et al., 2007) show the hardware resource consumption in the field programmable gate array (FPGA) Virtex-4 for the least mean squared (LMS) beamforming algorithm with full spectrum combining (FSC) receiver architecture and SIMPLE beamforming algorithm with symbol combining (SC) receiver architecture. Both scheme designs have an antenna array of 2 elements. The algorithm based on correlation requires less hardware. The main difference can be appreciated in the amount of digital signal processing oriented component (DSP48) resources, typically used for filtering applications (Martínez et al., 2007).

4.2 Receiver architectures based on algorithms type

Several receiver architectures can be implemented, and they are frequently based on the type of the beamforming algorithm used. When training signals are available in the transmitted frame, a time-based reference algorithm can be used. However, this solution is only valid when the earth station is capable of demodulating the received training sequence. Other algorithms used in deep space communications are based on signal correlation and they avoid performing the demodulating process. This kind of algorithms are blind techniques that do not require any additional signal demodulation before applying some beamforming technique and work better in low SNR conditions than time-based algorithms.
Several receiver architectures can be implemented exploiting the processing capabilities of the SDR, such as FPGA, application-specific integrated circuits (ASICS), and digital signal processing (DSPs). The design of the receiver architecture fundamentally depends on the selection of beamforming algorithms. An example of beamforming technique is the LMS algorithm whose estimation of coefficients or weights requires a temporal reference and is implemented through SC receiver architecture (Fig. 22.a). In the other hand, the SIMPLE algorithm (Rogstad, 1997) constitutes a beamforming technique that is implemented using FSC receiver architecture (Fig. 22.b) in order to perform the calculation of weights.

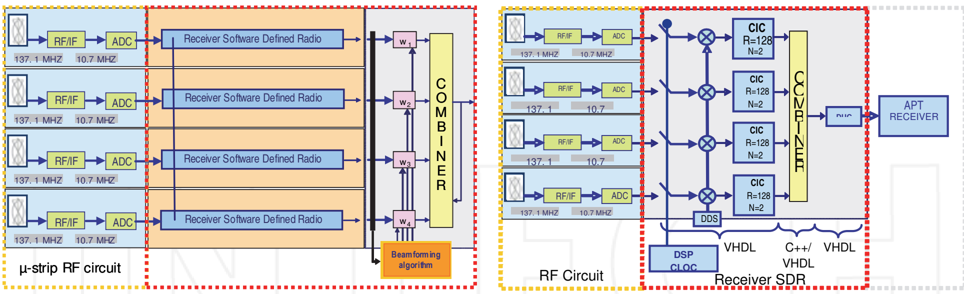


Fig. 22. Comparison of receiver architectures. a) Symbol Combining (SC), and b) Full Spectrum Combining (FSC).

The SC architecture can be divided into two more sub-classes which work on a phase-recovery basis. The complex symbol combining (CSC) recovers the phase information with regard to a reference element using feed-forward and feedback algorithms. One of the advantages of this scheme is that the rate of data sent to the combining module has a rate slightly higher than the symbol rate. For most applications, the symbol rate is relatively low and is a multiple of the data rate. In this kind of schemes, there is an important cost

consideration in real-time applications and the requirements of instrumental phase stability are very severe (Rogstad et al., 2003). Other type of SC architecture is the stream symbol combining (SSC). In this kind of scheme, data are sent to the combining module at a rate equal to the symbol rate. The symbol rate depends on the coding scheme and for most applications is relatively modest. Also, the requirements of instrumental phase stability are no severe, as in the case of CSC scheme. The disadvantage of the SSC is the additional hardware required for each antenna.

Furthermore, there are the baseband combining (BC) and carrier arraying (CA) architectures discussed in (Rogstad et al., 2003). In BC architectures the signal from each antenna is carrier locked and combining in baseband for further demodulation and synchronization. In effect, the carrier signal from the spacecraft is used as a phase reference so that locking to the carrier eliminates the radio-frequency phase differences between antennas imposed by the propagation medium. Besides, in CA architectures, one individual carrier-tracking loop is implemented on each array element. Then, the elements branches are coupled in order to increase the carrier-to-noise ratio (CNR), but losses of radio channel are far compensated (Rogstad et al., 2003).

In general, the selection of the beamforming algorithms is determined by the following aspects: Hardware and computational resources; Speed of convergence and residual error of adaptive algorithms; Calibration requirements and auto-compensation ability; and system signal-transmission characteristics.

4.3 Beamforming techniques for satellite tracking

Some satellites transmit useful information inside its frames for synchronization and tracking purposes. The gathering of satellite data requires the tracking operation along its earth orbit. To accomplish this goal with adaptive array architectures, some beamforming techniques should be implemented. Fig. 23 illustrates a simple example of a narrowband linear adaptive beamformer system.

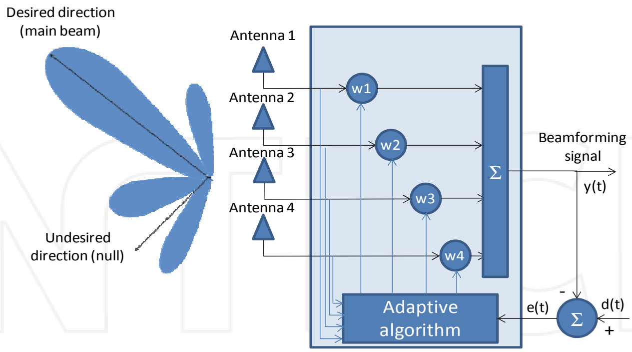


Fig. 23. Adaptive antenna system.

A linear beamformer combines signals according to some weights w_i, to produce a desired radiation pattern. The mathematical expression of a linear beamformer at the array output in vector notation can be expressed as $y = w^H x$, where x is the received signal vector to be combined, w are the weights computed by the beamforming algorithm and ^{H} denotes transposition and conjugate of $(\cdot)$.

In adaptive antennas design, weights are dynamically calculated with a certain algorithm in order to optimize some signal parameter like signal to interference-plus-noise ratio (SINR), SNR, or BER. An extended variety of algorithms exist in the literature for beamforming purpose and the most appropriated selection is done depending on the signal characteristics of the received signal.

4.3.1 Blind techniques

Blind beamformers make use of an inherent property of the received signal, such as the ciclo-stationarity of the constant modulus. In the latter, the algorithm eliminates the fluctuation of the signal amplitude and computes the weights to minimize the effect produced by those variations. The algorithms that make use of these methods are denoted as Constant Modulus Algorithms (CMA) (Biedka, 2001).

CMA algorithms present an important disadvantage: as the phase information is not considered, the constellation of quadrature phase shift keying (QPSK) signals commonly used in satellite communications appears rotated after beamforming, which imposes the need of an additional phase recovery subsystem in the array output.

4.3.2 Temporal-reference algorithms

Algorithms based on a temporal reference require a known reference included in the frame of the signal, such as training sequences, unique word (UW) or pilot bits. Thus, these schemes are normally used for digital signals. The aim of these beamformers is the minimization of the energy of an error signal integrated by interferences and noise. In order to reduce the order of the problem, the weight calculation is usually done iteratively.

The most popular adaptive filters are the LMS and Recursive Least Squares (RLS) algorithms (Haykin, 2002). Briefly, the main differences lie in the method to calculate and the final convergence behavior: while LMS has a linear complexity order with the number of antennas in the array, RLS makes use of matrix operation, so that the complexity order is quadratic, but the convergence is faster.

An interesting alternative to the LMS is the Normalized LMS (NLMS), which normalizes the adaptive step to avoid variation during the convergence process. The counterpart is the more intensive processing requirements to calculate signal power and normalization operation.

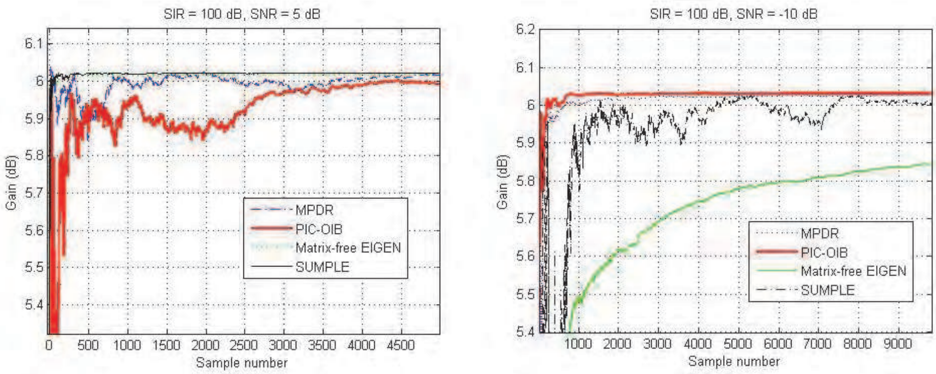
4.3.3 Correlation-based algorithm

In contrast to beamformers based on temporal reference, schemes based on signal correlation do not require the demodulation of any signal. These techniques are the most popular to extract the spatial information for beamforming, and we have focused on the use of the SIMPLE algorithm (Rogstad, 1997). This algorithm has been used by the Deep Space Network (DSN) of National Aeronautics and Space Administration (NASA) to combine the signals received from spatial probes in radio telescopes located in different sites around the Earth surface. The main disadvantage of correlation based schemes is the lack of ability to cancel interference signals.

4.4 Performance comparison

Some simulation comparisons between spatial and blind algorithms are presented to show benefits and drawbacks. Four algorithms have been selected with a 4-element uniform linear

array (ULA). The spatial algorithms simulated are post-beamformer interference canceller – orthogonal interference beamformer (PIC-OIB) (Godara, 2004) and minimum power distortionless response (MPDR) (Van Trees, 2002). On the other hand, the blind algorithms are the matrix-free EIGEN and the SUMPLE (Rogstad, 1997). The convergence process is compared as a function of the input SNR as depicted in Fig. 24.
As it can be observed from the above results, spatial algorithms outperform blind ones at low SNR, and vice versa. On the other hand, with medium-low SNR and low or absence of interferences, the behavior of all algorithms is quite similar.



a b

Fig. 24. Convergence behavior of spatial versus blind algorithms in the absence of interferences with several input SNR. a) SNR = 5 dB, and b) SNR = -10 dB.

5. Experimental Test-Bed based on SDR platform

This section presents a test platform known as Adaptive Antenna Array Test-Bed - A3TB, where a comparative study of several beamforming algorithms can be performed and modularity of the architecture is a well proved advantage. The test bed is based on SDR technology and uses a novel architecture that can be used with both blind and spatial-based beamforming algorithms. The A3TB concept can be applied to a number of scenarios as the current version is independent of the signal properties. Simulation results using the A3TB with the APT channel from NOAA satellites show the performance of the concept and the feasibility of the proposed implementation.
The scope of the system development was is to prove the concept of antenna arrays applied to ground stations instead of reflectors for different applications, such as telemetry data downloading or end-user in mobile applications as discussed in the introduction section. In contrast to reflector antennas, antenna arrays offer the possibility of electronic beam-steering avoiding the use of complex mechanical parts and therefore reducing the cost of the antenna. It is also a good chance for Universities and Research Centers aiming to have their own ground station sited in their installations.

5.1 A3TB concept

The A3TB can be defined as *a software-defined radio beamformer applied to a ground station for tracking LEO satellites*. The novelty relies on the use of an antenna array to smartly combine

the received signals from the satellite and its implementation based on SDR technology. The reason to use an antenna array instead of a single antenna is to electronically steer the beam in the direction of the satellite along its orbit without requiring a mechanical system for tracking. In addition to the advantages of the use of SDR technology and antenna array, it is the modularity and flexible architecture implemented in the A3TB. Fig. 25 shows the A3TB architecture where it is evident the feasibility to update or change during operation any of the main blocks. It is possible to change during operation the beamforming algorithm and to include new beamforming modules to the system. Furthermore, changes on the BENADC are possible to implement not during operation, but new receiver architecture at off-line such as those options discussed at follow.

In (Salas et al., 2007), the block diagram represents the software system implementation of the first version of the test-bed prototype and most of it is based on VHDL. Depending on the firmware, three options could be installed into the FPGA Virtex4. The option A is implemented with the signal processing on the PC, so the SIMPLE beamforming is done in the module developed in C++. The option B is implemented completely on VHDL and this option need to export the beamforming weights just to draw the array pattern diagram. Finally, in contrast to the option B, the option C is implemented for the LMS beamforming algorithm.

With the first version of the Test-Bed, the modularity on the selection of firmwares was proved switching between A, B or C receiver architectures, and an important result of the Test-Bed development is the hardware resources occupation presented in (Salas et al., 2007).

The advantage of the SDR implementation is that A3TB architecture can be used to process any received signal from a LEO satellite in the appropriate band imposed by the RF stages. Moreover, most of the processing tasks are performed on software, using appropriate routines to process any receive signal. There are 2 main schemes to implement the beamforming stage: SC and FSC [41]. Both schemes are compared in Section 4.2.

The current version of the A3TB in Fig. 25.a was updated to track NOAA satellites in the VHF band, in particular the APT channel. Previous versions of A3TB dealt with LRPT signals from MetOp-A, where a complete receiver with beamforming and synchronization stages has been implemented(Salas et al., 2007; Martínes et al., 2007).

5.2 Implementation of the A3TB

The A3TB prototype consists of 4 main parts as shown in Fig. 25.a. The first part is the antenna array, which has 4 crossed-dipole antennas as depicted in Fig. 25.b. The second part consists of RF-IF circuits which amplify and down convert to IF incoming signals. Furthermore, an automatic gain control (AGC) was implemented using two steps of variable attenuators in the IF domain.

The third part is the SDR platform which consists of the beamforming algorithms implemented on C++ and the FPGA firmware on VHDL, PC and BENADC blocks show in Fig. 25, respectively. The hardware resources occupation for this Test-Bed implementation is similar to one presented in (Martínes et al., 2007). The last part is the software from weather satellite signal to image decoder (WXtoImg) on the PC using the sound card output/input in order to get the weather satellite image.

Since the implemented architecture is FSC the demodulation is not required and the IF signal is digitized. For the signal processing hardware design the BenADC-v4 has been chosen. This solution includes a FPGA Xilinx Virtex4-SX55 with four 12-bit analog inputs at

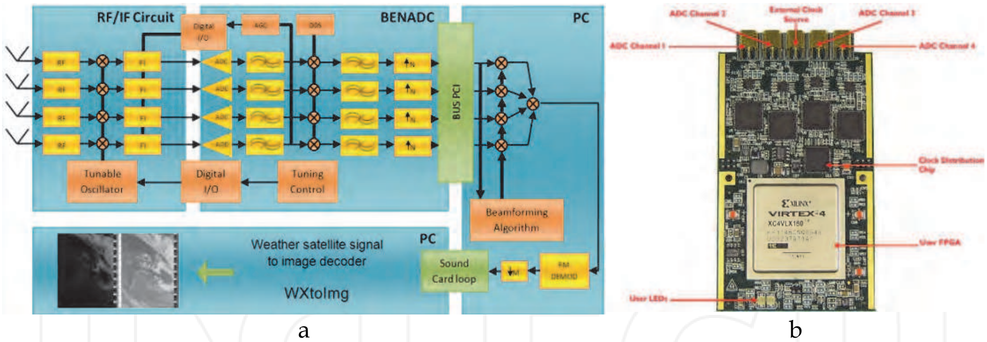


Fig. 25. a) Block diagram of the A3TB, and b) BenADC – Virtex 4-sx55.

250 Msps (Martínes et al., 2007). Digital samples are transferred to the PC where beamforming and subsequent APT demodulation of the array output are performed using C++ routines. This implementation design offers higher flexibility for testing different beamforming schemes. Finally, demodulated APR frames are sent to the WXtoImg software to show meteorological maps.

The A3TB is controlled by the PC for simulations and field trials. The graphical user interface allows presented in (Salas et al., 2008) the user to choose the beamforming algorithm and set all the parameters of the LEO satellite for tracking such as the number of antennas of the array, distance between the elements, direction of arrival and IF frequency. The C++ routine calculates the beamforming weights and plots the synthesized array factor. Subsequently, the reception of meteorological images has real time system requirements. Thus, it is necessary a data transfer from the FPGA to the C++ module to process the samples continuously, and give APT frames to the audio output of the PC. Since, the meteorological satellites often have a low baud rate, in the case of study with NOAA satellites the data transfer is made using two buffers controlled by a thread.

It is important to mention that the A3TB with SDR architecture can evaluate different beamforming algorithms and receiver schemes. The update of A3TB for larger arrays is immediate, as the basis for algorithms is independent of the number of elements in the array. The architecture of a new ground station concept to track LEO satellites based on software defined radio and antenna arraying as Test-Bed is a well proved choice to evaluate future antenna array architectures for satellite communication and benchmark features of the proposed system. As the A3TB VHF version is based on FSC scheme, the concept can be applied to a number of satellite tracing scenarios.

6. Conclusions

The performance analysis of different beamforming algorithms is an important issue in the new generation antenna array development and research. Thus, A3TB helps to analyze beamforming algorithms paving the way for testing and debugging for posteriori use in larger arrays, such as GEODA. Results obtained in real scenarios with A3TB state, for example, that spatial reference algorithms such as MPDR should be used in the absence of interferences, whereas blind algorithms are appropriate for low SNR conditions. Finally, the A3TB can also serve to validate the performance of calibration procedures.

In future work, the A3TB will deal with the system combining of full modularity with the capability of change firmwares based on the first version design of the Test-Bed, plus the flexible architecture of the current design of the Test-Bed based on VHDL, C++ and Antenna Arraying. Furthermore, the addition of more modules to increase the number of antenna array elements is evident in next generations.

7. Acknowledgment

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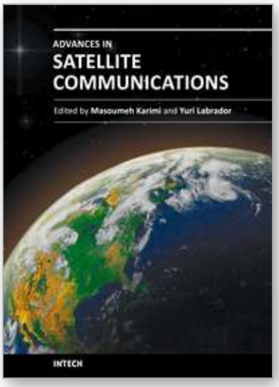

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Satellite communication systems are now a major part of most telecommunications networks as well as our everyday lives through mobile personal communication systems and broadcast television. A sound understanding of such systems is therefore important for a wide range of system designers, engineers and users. This book provides a comprehensive review of some applications that have driven this growth. It analyzes various aspects of Satellite Communications from Antenna design, Real Time applications, Quality of Service (QoS), Atmospheric effects, Hybrid Satellite-Terrestrial Networks, Sensor Networks and High Capacity Satellite Links. It is the desire of the authors that the topics selected for the book can give the reader an overview of the current trends in Satellite Systems, and also an in depth analysis of the technical aspects of each one of them.

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